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GENERAL INFORMATION

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PROBLEMS OF DEVELOPMENT OF DENSELY SETTLED AREAS

and

SCIENTIFIC POSSIBILITIES FOR INCREASING THE WORLD'S FOOD SUPPLY

THE AMERICAN PHILOSOPHICAL SOCIETY
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Papers read at the Annual General Meeting of the Society, April 20, 1950

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POPULATION TRENDS IN DENSELY POPULATED AREAS

ALVA MYRDAL

Principal Director, Social Affairs Department, United Nations

(Read April 20, 1950, in the Symposium on Problems of Development of Densely Settled Areas)

INTRODUCTION

THIS occasion when population problems are to be discussed by the American Philosophical Society ought to be gratefully hailed as a very important one. Certainly, all social sciences and not least the science of demography, urgently need attention to their fundamental problems of method, of drawing the demarcation lines between facts and values, between conclusions and opinions. The more the philosophers could aid in throwing light on the involved epistemological riddles of the sciences which focus on human behavior, the better it would be for the world. For the world needs to rely on these sciences. The world in our juncture of international tension and national planning certainly needs to know very much more of what the real prospects are with regard to the growth of world population itself, to the different processes of change in different parts of the world, to the probable social and economic effects of these changes and to the possibility of influencing and directing such changes.

The term "densely populated areas" has an appealing semblance of exactness. I am afraid, however, that it is not very much more than a euphemism, substituted for the ill-fated term "overpopulated areas." If we take the term at its face value, i.e., regions where the density of population in relation to space is greater than average, we would group together countries where *problems* are not at all similar, i.e., all of Europe (except Scandinavia), India, China, Japan, Philippines, Java, and the Caribbean Isles. In the other category, of sparsely populated space, we would find the two American continents, Africa, most Arab countries, Oceania, and the USSR. The "densely populated areas" thus present highly varying patterns, which is in itself a salutary reminder that the availability of space is not the determining factor in population.

We get, as a matter of fact, two characteristically different groups of countries in the category "densely populated." One is that of countries which have a high density of population and enjoy a standard of living higher than the average, as in Europe in general and Western Europe in particular. A radically different pattern is found in countries which are both densely populated and definitely poor. I believe that it is this group, chiefly embracing the Asian countries I mentioned (except Japan) as well as the Caribbean ones, which is uppermost in the minds of those demographers who increasingly use the term "densely populated areas," when they want to avoid the term "overpopulated," since that term is objectionable on scientific as well as political grounds. We thus come to a refinement of the term, as what we mean are "densely populated areas with considerable poverty." In effect this is practically synonymous with "densely populated areas dependent chiefly on agriculture."

Their poverty is the practical problem which has in our days—and this is a homage paid to the growing internationalization of our social conscience—mobilized world attention. The main theoretical problem is to find the causes of differences; but the trouble is that the quietude required for a theoretical study is disturbed by the urgency of applying the theoretical findings to solve practical problems which are growing ever more acute. For the population in many of the poverty-stricken, densely populated areas does not remain static, but is increasing and likely to increase faster in the future. Hence the eagerness to solve "population problems" which inspires so many prophets with so many sermons about world resources and world populations.

BASIC FACTS

I may, perhaps, for those who are not demographers, go rapidly over some well-known facts and arguments which provide the setting for the problem.

Our knowledge of the facts of population growth in densely populated agricultural regions is very scanty. In some of them, notably China, there has never been a census in the modern sense, and even the size of the total population is only

vaguely known. We do not know whether growth has actually occurred. In others, there has been a long tradition of census-taking. In India, for example, censuses have been taken regularly for about seventy years. In the first fifty years, decades of growth alternated with decades of stagnation. Between 1921 and 1941 (the date of the last census) there were two decades of fairly rapid growth, and the population enumerated increased at the rate of 1.2 per cent per annum on an average. Altogether, between 1872 and 1941 the population of India[1] increased from about 250 millions to about 390 millions. In several other Asian countries—Burma, Ceylon, Malaya, Java, the Philippines—even higher rates of growth have been recorded than in India. Some of this growth may be due to deficiencies in the censuses—the rate of growth may be exaggerated, for example, by the increasing accuracy of successive enumerations. But there is no reason to doubt that considerable growth has occurred in many areas. There is, however, reason to suppose that in those areas where no censuses have been taken, China for example, conditions have been less favorable to growth than in the countries I have mentioned, and population may have remained constant.

It is clear that growth at a constant rate of even 1 per cent cannot have proceeded for long in the past. What has brought such growth about in recent decades in many densely populated countries?

There seems no reason to believe that birth rates have in recent times been significantly higher than they used to be. There are, however, reasons which suggest that the death rate has declined in many areas. In many of these areas there are reports from earlier days of famines on a scale which no longer seems to occur there. We have reports on the efforts to control epidemic diseases and of their success in these areas. In some instances we also have statistical evidence supporting the view that death rates have declined. What seems mainly to have happened in many cases is that the abnormal peaks of high mortality due to famine and disease have been levelled out.

Birth rates appear still to be roughly at the level which was used to maintain the population in the fall of the high mortality which formerly prevailed. Marriage and childbearing habits appear to have remained substantially unchanged since that time. Where series of birth rates are available (for example Egypt, Ceylon, Formosa, Korea) they confirm this view.

Reductions in mortality, or even in many areas the maintenance of mortality at existing levels, will then, given the level of birth rates, involve tremendous population growth. The magnitude of the growth which may occur can be appreciated by considering what is involved if the countries which we are here discussing would be brought to a level of mortality comparable to that of Western countries—and it must surely be our aim as members of the international community to give to everyone wherever he or she may be the same chance to lead a long and healthy life.

In fact, however, at current death-rates, the average length of life—usually denoted by the "mean expectation of life"—is probably, in most of the densely populated areas, one half or even less of what it is in the Western countries. If the number of births were to remain constant, but every baby born were to live twice as long, the population would automatically be doubled. Such a process would in itself have tremendous implications in a country such as India, where a population about as large as that of Europe (west of the USSR) is already about as densely settled on an average as that of Germany or Italy. Yet the population will double even if the number of births merely remains constant. But as the number of persons of childbearing age increases, the number of births will grow as an automatic result unless an incredibly rapid reduction of fertility takes place. Once the number of births is increasing, as it is at present, a cumulative process is started, for the additional ones born now will themselves be of childbearing age in a few years.

The argument suggests that we must expect most of those populations with which we are concerned to be multiplied in the long run, by a number a great deal larger than two, if they are to reach the low levels of mortality obtaining in the West.

It is not my task to discuss here the economic implications which spring to mind. The increase in production which is involved in bringing all mankind to Western levels of mortality is proportionately far greater than the increase in human numbers of which I have spoken. For the maintenance of low mortality depends upon a vastly higher standard of living or, in other words, a much higher output per head than obtains in countries of high mortality. How such

[1] These figures relate to India before the creation of Pakistan.

a drastic economic change can come about or even whether it can come about—the problem of the sufficiency of resources—I do not propose to discuss.

THE PROBLEM OF PROGNOSIS

My subject is rather the prospect of an eventual cessation of growth as a result of a decline in fertility. It is clear that ultimately growth must be halted by this means if a boomeranging rise in mortality is to be avoided. Moreover, it will make a great deal of difference how large is the growth which occurs in the transition and in many countries it will be important that growth should be small. It has often been agreed that the whole development towards higher standards of living and low mortality can only come to a successful conclusion when fertility falls fairly soon and falls rapidly. Otherwise, it has been suggested, there may be a danger that the population growth resulting from reduced mortality may bring about famine and end in catastrophe.

What are the prospects for a decline in fertility in the countries which we are discussing? This question is often answered by pointing to the experiences of Western countries in the past two centuries. There also the technological evolution first caused a reduction in mortality which resulted in a spurt of population growth and growth was later halted by a fall in fertility. It may be supposed that events will follow a similar course elsewhere.

But what right have we to make such an assumption? What right have we to lump together very intricate causative processes in sweeping terms like "industrialization," " economic development," "urbanization," "improved standards of living" and then take for granted that a similar course of events will unfold itself in the new countries with a similar series of effects. It is sounder, and indeed necessary, first to stop at what we definitely know about trends in the countries which are themselves under study, and secondly, perform a much more detailed analysis of the potential strength of the different causative factors.

Mortality is always lowered by reducing the health risks in the environment *and* by strengthening the human being's resistance against such risks. This has been done in one way if we look backwards into history and dwell upon Western society; it might follow somewhat other patterns and another pace in the future.

The factors which may bring about a decline in fertility may be usefully divided into those which operate independently of human intentions, such as biological changes, and those which, like the postponement of marriage or contraception, are human acts deliberately designed to restrict the numbers of births. There is no doubt among the scientists as well as among those who just use their common sense that the major direct cause of the reduction of fertility in Western countries has been the private planning of family size.

This is what we might call the *first line of causation processes*, influencing death rates and birth rates.

The second line of causation is to search for the causes that in their turn lead to eliminating health risks in the environment, increase human resistance against such risks, effect human fecundity, lead to postponement of marriage, or family limitation. There enters a rich interplay of factors, which, however, should be studied, *and if possible, measured*, before we lump them together as an indiscriminated compound labelled "industrialization" or "economic development." I might first mention some of those which in different countries, to a lesser or larger degree, have been influential in reducing the death rate. Their comparative efficiency is a problem to study—and for the sake of predicting the future one of the most interesting problems. For example, it may be that one of them in a given situation is extraordinarily strategic in comparison with the others:

Improved transportation, aiding to overcome local famines in the midst of national plenty.

Control of epidemics. Sanitation measures, pure water supply, sewer disposal.

Factory legislation and safety devices, diminishing occupational hazards.

Improved personal hygiene (efficiency of educational campaigns).

Improved housing hygiene (efficiency of public control of buildings, introduction of so-called modern conveniences—baths, water-toilets, etc.)

Now—here is a wealth of research problems. What are the comparative efficiencies of these various factors? What is the most efficient timing of their introduction? Which ones work in comparative isolation—e.g., control of communicable diseases? How do they interact and reinforce each other's influence?

The "causes" behind any decline in fertility are, of course, an even more complex compound of processes, as yet fairly incompletely under-

stood. Where we would need the aid of philosophers is exactly for an analysis as to the different steps in this social causation: the technically instrumental causes like contraception or postponement of marriage in the first line, the question of psychological motivation for contraception or for postponement of marriage in the second line, the question of economic and social factors influencing this psychological motivation in a third line, etc. As natural resources, social values, family patterns, religious controls, etc., are highly variable in these countries and nowhere exactly like the conditions in early Western Civilization, it must be surmised that it is unlikely that the developments should be a copy of those occurring in the West.

SIMILARITIES AND DIFFERENCES BETWEEN EARLY WESTERN DEVELOPMENT AND EXPECTED DEVELOPMENTS IN NEW COUNTRIES

Certain elements of Western experience may, however, be useful for evaluating the prospects in densely populated countries. Unlike the case of mortality, technological advance does not seem to have directly provided new means which had an important influence on the spread of family limitation. New techniques of contraception, though they have been invented, have not played a role comparable to new techniques for fighting diseases. Family limitation by methods known for thousands of years seems to have begun to be widely practiced in many places in the West, owing to certain transformations in economic and social conditions and in values and attitudes. The direct influencing of public opinion also played a subordinate part. For example in England, very intensive propaganda for family limitation was carried on apparently without effect for fifty years, in the nineteenth century, while in France at the same time, the size of families was being reduced while there was relatively little public discussion of the subject. What seems to have happened is that, mainly for economic reasons, children became more and more of a burden while at the same time attitudes changed in such a way that people were willing to control the size of their families. Parenthood could become a matter of "rational" calculation.

We may suppose that in the densely populated countries also family limitation will take place only when and if similar profound changes in attitudes occur.

There is very little evidence to determine whether family limitation is already widespread in at least some sections of the populations of the densely populated countries. In a sample study in Calcutta, 38 per cent of the upper class interviewed stated that they had attempted to limit their families. In this group the average number of children which had been born alive to women over forty years of age was 5.6 compared to 6.3 for the lower middle class group in Calcutta, and 7.5 in rural areas.

Some differences between the fertility of urban and rural groups in India and elsewhere which the statistics seem to indicate have been interpreted as the beginning of the spread of family limitation by a process analogous to that experienced in the West. Urbanization and industrialization, it has been said, create conditions where children are a burden and help create the attitude which is sensitive to the burden and reacts by means of family limitation. So in the densely populated countries, industrialization and urbanization would seem to come first, followed after an interval by a reduction in family size. The argument may be supported by appealing to the example of Japan, where, though the cultural background is completely different, industrialization seems to have had just this result—after a certain time lag.

There is, however, no unique pattern along these lines even in the West. Countries which are in other respects largely similar have sometimes had very different fertility histories, for example, families in Holland are much larger than in neighboring countries. Family limitation has sometimes developed in rural areas. For example, in France such limitation began much earlier than elsewhere by making headway among the peasantry. There is evidence of similar developments elsewhere, for example in Hungary, and on the Swedish island, Gotland, where farmers lived in a closed community.

In rural areas the spread of family limitation has often been connected by demographers with the desire of peasant owners to avoid splitting up their property between several sons. It would, however, be an important problem of research to analyze more precisely how in particular times and places the economic consequences of large families among peasants came to be felt so strongly and how the attitudes were created which led to the adoption of family limitation. Such patterns and quite new ones also may develop in the densely populated countries.

In the case of mortality, there are strong arguments to suggest that death rates may be reduced more rapidly in the densely populated countries than they were formerly in the West. The medical knowledge and techniques accumulated in the West are ready to be used in the densely populated countries. There are also many aspects of modern Western technology which are not directly medical but which nevertheless are of great importance for public health services—for example, the enormous development of rapid means of transport. There are recent examples which suggest that considerable reductions in mortality can easily be obtained with modern techniques. The most notable example is perhaps Ceylon, which in 1946 is recorded to have had a crude death rate of 20 per 100 with little change in the preceding fifteen years. In 1947 the death rate was 14 and in 1948 only 13 per 1,000. This reduction has been attributed to the efforts of the medical services and particularly to a concerted attack on malaria by means of DDT. A very rapid reduction in the death rate from malaria has also been reported in Puerto Rico, where the death rate from this cause declined from 125 per 100,000 in 1941 to 32 in 1946, and the total crude death rate declined from 19 to 13 per 1,000 in the same period.

These and similar examples come from areas which are relatively well supplied with doctors and medical services, and in general are more advanced than the larger countries of Southeast Asia. Moreover, these sudden reductions of mortality may not be maintained. But there are forces active in the world today which suggest that such a strategic eradication of certain diseases could go forward at unprecedented speed. We can point not only to the development within the countries concerned; as an official of the United Nations, I may be excused for directing particular attention to the increasing international sense of responsibility in this matter and the increasing willingness to shoulder these responsibilities. The UN is only just beginning its activities in the field of technical assistance. Of the UN organs, the World Health Organization and United Nations Children's Emergency Fund are particularly bent on schemes for eradication of mass diseases, such as yaws, syphilis, malaria, and tuberculosis.

It may be wishful thinking that these schemes will have any great and lasting effect without a long range improvement of living conditions and health care, which costs more money, more time, and more sustained effort. But even these may be expected to be more purposively applied than was the case in nineteenth century Europe. Thus, an acceleration of this change might reasonably be expected.

In the case of fertility there is no comparably clear factor which distinguishes the present situation from the earlier situation of the West. Nevertheless, one may point to certain broad tendencies in the modern world which tend to hasten the kind of developments which lead to the decline of both mortality and fertility. In assessing the prospect of declines in fertility, the most important questions are, as has been pointed out above, when and how strongly will the families in these regions sense and react to the pressures which arise as a population leaves the traditional self-contained agrarian life, as parts of the population get into the wage earning classes, as compulsory schooling and/or prohibition of child labor takes away the earning capacity of children. Then the larger family will be at a greater disadvantage than the small one. We do not know whether there will be either more or less reluctance on the part of the families in these new countries to recognize these economic facts, more or less resistance to introducing family limitation. Such questions can only be answered by studying individual groups.

Some ingredients in modern life do work to spread the creation of an atmosphere favorable to family limitation. One such new factor is *the increased velocity in communication.* The cultural inertia may not be taken for granted to be the same in the now developing countries as in, say, the West when industrialization first set in. The means for spreading information, for introducing rationalism in education are quite different. The mass media are already in their commercial form working in that direction.

More purposively the literacy campaigns of our days, as guided on a large scale by UNESCO, are very different with regard to subject matter from the formal school education that was gradually introduced in the West. It is no longer simply a question of teaching the other half of mankind to read, but to get "fundamental education" which is defined as being at the same time basic literacy training as elementary health education, instruction on fundamentals in agriculture, etc. What is here introduced as a new element is in one word a sort of basic training to apply scientific and technical knowledge. In turn, this is a training towards much more rati-

onal attitudes. Demographers who want to prophesy should take into account these new means for spreading knowledge and changing attitudes.

Another new factor, and one that might easily be of an importance that far outweighs many others, is the *prevalence of economic planning and Government control*. So definitely is the cultural-political trend in the world of today one towards planning, that comparisons with the liberal era of Western society should be used very cautiously. It is almost certain that in most of the under-developed countries with large populations and high birth rates, the next decades will see a rapid development along the following lines. On all sides there will be an attempt by the state to strengthen its hold over the inhabitants of its territory, and to extend its control over social and economic development. The very recognition of their being "under-developed" will for these countries be an extra reason to attempt a short cut by way of planning. Practically everywhere there will be planned attempts to rationalize agriculture, to speed up industrialization and generally to bring about a fuller use of resources. Probably in all countries, the community will also be bent on improving health and thus lowering the death rate. Even if the state might rarely make a systematic effort to curb the birth rate, there will be health services available, there will be a social concern for what happens to the family's health, and thus family spacing may at least come to be recommended. There is no valid ground to expect that such features will in the new countries have to wait until a long era of industrialization and urbanization has passed.

THE IMPORTANCE OF INTERNATIONAL FORCES

These two factors, increased efficiency in communicating knowledge and increased tendency to plan, can be used to spread a great number of different influences: change in religious values and inhibitions, a new respect for the individual and for the duty to keep alive a baby once born, more independence in the status of women, etc. At one interesting junction the two may be seen working together and, presumably, working for reducing the time lag between the potential increase in population, due to reduced mortality, and the ensuing adjustment of the birth rate. That is through international action. Easier spread of cultural influences and more definite Government planning means that UN and other international bodies can presumably wield greater influence on the development within these countries. But these influences go in one direction only: campaigns are on for fundamental education about scientific data relating to simple life problems, for human rights, for establishing health services, etc. There is even a definite pressure from abroad, e.g., for raising the status of women. This force was not in existence in the earlier times from which we draw our knowledge. Thus, there is reason to expect a *different* course of events, and, I dare say, one slightly more rational. That is, if the world is left in peace and without corruption of the international forces now assembling themselves for progress.

The advice of the demographers, sociologists, and cultural anthropologists is urgently needed when new development is being planned. What factors of change should be introduced in what sequence? There is still considerable confusion behind such plans as the Point Four program. Economic development and social progress are the professed objectives of everybody. But those trained and educated to plan economic development and improve productivity might easily tend to introduce Western technological elements without due preparation in the social and cultural environment of the underdeveloped countries. On the other hand, some of those who wish to defend the social well-being of the peoples, the preservation of their innate dignity, and the avoidance of abrupt population increase might tend to retard development and cultivate romantic village primitivity. What is desirable is undoubtedly a more balanced modernization, a more subtle timing of the changes introduced.

If a thoroughly underdeveloped and densely populated country, agricultural society were to offer itself for a demonstration in development, and starting with a maximum of rational clarity, it might well be that its authorities would prefer to see planned a gradual development, going through some three stages, directing the stimulation for successive changes at subsequent generations. In the very first stage would be introduced simple improvements which can be afforded with a minimum of taxes and savings:

a) Improving agricultural methods, seeds, tools, so as to get a greater yield from the acres which are already cultivated.

b) Eradication of mass diseases resulting in higher survival values but also greater vitality.

c) Some simple fundamental education, including basic agricultural techniques, hygiene rules with perhaps some clarification about sex facts, domestic education, and similar practical subject matter for learning.

d) Some rural social centers—as the only form of "social services"—in order to practice cooperation for community organization, and offer a center for stimulation to improved modes of living.

The young ones might be aided to move into a second stage, a more moneyed economy. Their needs would be for:

a) Vocational training, particularly for small industry, local commerce, road building and transportation.

b) Improved health services, hospitals and health controls.

c) Schemes for planned saving with certain public incentives and under-writing for wise saving for specific long-range consumption goals.

d) Encouragement of investment of private savings particularly in cooperatives and in housing.

e) Development through all these means of local self-government.

In a third stage the transition to mechanization, to a complete national school system, complete health services and social security would be carried through with the participation of *citizens*, duly prepared for the transition and capable of directing their own destiny.

This scheme is blueprinted, not for the sake of population development, but for the sake of promoting true welfare and, more directly still, for the sake of democracy. It is participation in economic development, not exploitation of economic resources, that at least the international organs are working for when they want to pool the world's "know how" in an international Technical Assistance Programme. What I am trying to stress is that the fulfillment of this aim may almost incidentally also provide the setting for a more rapid acceptance of fertility reduction through family limitation. Once more I need to stress, however, that this does not amount to saying this is the *probable* future ahead for these countries, only to stressing that it is a *possible* new development course with regard to population.

I cannot end without making some apologies if I have raised questions as an introduction to the following discussion rather than given you the array of facts that might have been expected of me. But the facts are so easily available in all kinds of textbooks. UN has also aided in providing a very handy reference pamphlet on exactly what was the title of my paper: "World Trends in Population." There are, however, many problems that an official organization does not give room for in its publications, while a private person, even if a UN official, must be free to raise them. And I could not let this opportunity pass without trying to direct to this particularly qualified audience questions as to some of the fundamental problems in demography which we have as yet left unsettled, and perhaps a plea that that rarest of qualities should be applied to social problems—*human reason*, which the founding father of this society, Benjamin Franklin, and his age so persistently defended. With greater doses of reason applied, both the population development and the social well-being of regions now underprivileged could hail a much happier future.

POPULATION AND THE FURTHER SPREAD OF INDUSTRIAL SOCIETY [1]

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FROM a world standpoint the transition to industrialism is still in its infancy. Incomplete even in the West, it has barely started (though its effects have been felt) in the rest of the world. Mankind thus finds itself at the critical point in a socio-economic revolution transcending anything ever known in the past. Those peoples still in the *previous* stage of development—the pastoral and agricultural stage—suffer an extreme disadvantage vis-a-vis the more advanced peoples. Not only are they poorer, but, since the presence of industrialism anywhere affects men everywhere, they have been caught in a worldwide economic and political net that has exploited their weakness, and ironically, affected their opportunities for acquiring industrialism.

To contemporary eyes the spread of industrialism may seem painfully slow, but viewed in archeological perspective it is amazingly rapid. Premonitory signs and conditions aside, the actual transformation came in the last 150 years.[2] Since borrowing is easier than invention, the recently industrialized areas (U.S.A., Australia, Argentina, Japan) have made the transition more rapidly than did northwestern Europe; the pace of industrial change has tended to accelerate.[3] There are reasons to believe, therefore, that the transformation may become worldwide within a century or so.

It is not surprising that the fast rise and spread of such a fundamental transformation has given rise to insecurity and turbulence in human society, particularly in view of the sharp regional inequalities created by a partial industrialization of the world. A new kind of insecurity has been born, an insecurity not so much of bread (though that too still occurs) but of institutions and social expectations. A new scale of conflicts has been reached, global in scope and armed with the newest psychological and material weapons of our latest stage of civilization. This turbulence, however regrettable from a humanitarian standpoint, is functional in the great transformation, for it is by the cataclysmic occurrences that old ways of life can be sloughed off hastily; it is by instability that new modes of stability can arise. The archaic agricultural regions of the world are now the battleground. Because they are weak and poor, because they are industrial vacuums, because they embrace huge areas and large populations, they are important pawns in the struggle. They face the greatest potential change and hence the greatest instability.

THE DIMENSIONS OF AGRICULTURALISM

A country can be safely regarded as still in the peasant agricultural stage if more than 50 per cent of its gainfully occupied males are engaged in farming, fishing, hunting, and forestry. This definition excludes the type of nation whose economy rests primarily on products of the land but whose farming is mechanized. The latter cannot have half of its occupied males in agriculture, because mechanized farming requires little labor and yet produces a sufficient surplus to support a substantial labor force in secondary and tertiary industry.[4] Since this kind of country is sometimes called "agricultural," a better designation for the type that interests us would perhaps be "non-mechanized." But regardless of the name the distinction is clear, as our data will show.

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[1] From the Division of Population Research, Bureau of Applied Social Research, Columbia University (Publication No. A-122 of the Bureau).

[2] Levy, Marion J., *The family revolution in China*, 274–278, Cambridge, Harvard Univ. Press, 1949.

[3] Heaton, Herbert, *Economic history of Europe*, 417–418, N. Y., Harper, 1936.

[4] Argentina is a case in point. Though it depends heavily on agricultural exports, less than a third (approximately 30 per cent) of its occupied males are engaged in agriculture and 48 per cent of its population lives in cities of 20,000 and over. Its agriculture is highly mechanized and rationalized. See Kingsley Davis and Ana Casis, *Urbanization in Latin America*, 17–21, N. Y., Milbank Memorial Fund, 1946 and Carl C. Taylor, 105–123, 143–148, 274–290. *Rural life in Argentina*, Baton Rouge, L. State Univ. Press, 1948. Another illustration, the case of New Zealand, is discussed later.

WORLD DISTRIBUTION OF PEASANT AGRICULTURALISM

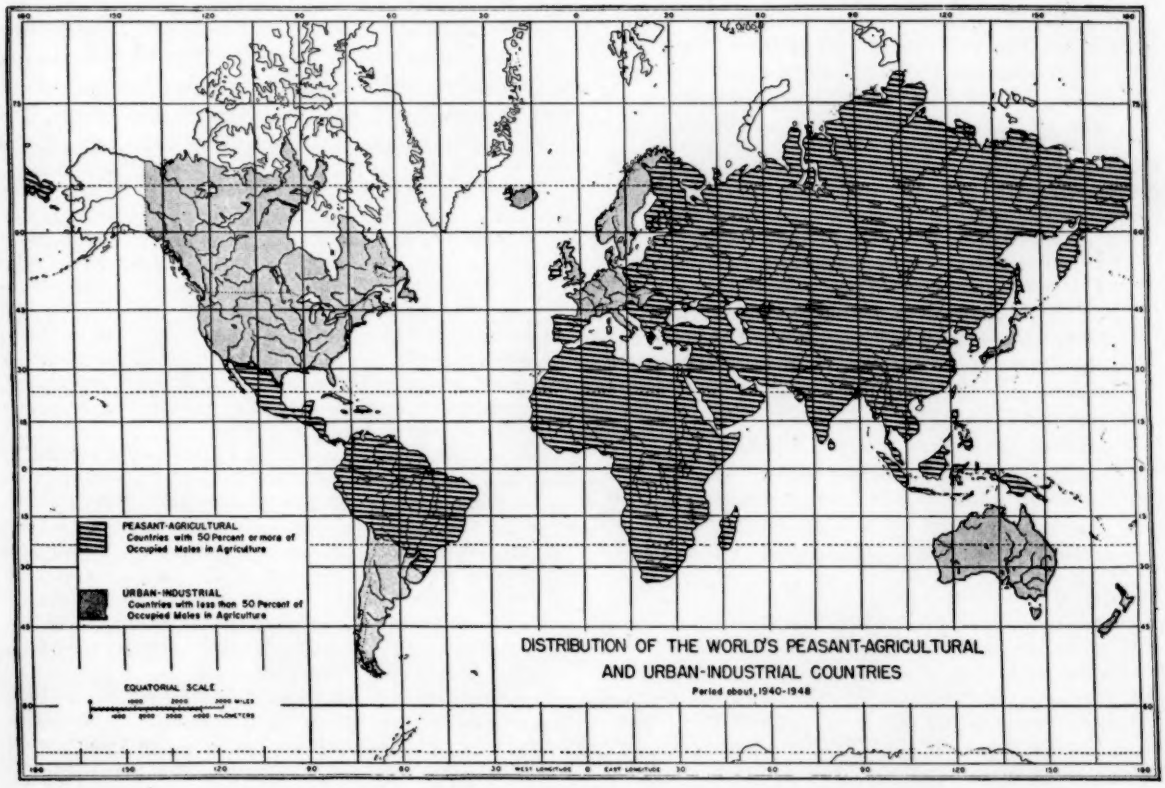
Applying the 50-per-cent criterion and using computations and estimates prepared by the Bureau of Applied Social Research for dates around 1940–47,[5] we find that the non-mechanized, or archaic, agricultural countries and colonies embrace 74 per cent of the world's habitable area and 76 per cent of its people. They are distributed by major continents or regions as shown in table 1 and map 1. Their location is seemingly governed in the main by the complex interrelations of climate, indigenous population density, and accessibility to international trade. It is a striking fact, for example, that archaic agriculturalism is heavily concentrated in tropical areas, modern industrialism in temperate areas. One possible explanation of this fact is that tropical climates are a deterrent, though not an impregnable barrier, to industrial development. However, it would appear to be also true that industrial retardation in tropical areas is due in greater degree to their past success as agricultural regions, to their uncongeniality for persons of temperate-zone European culture, and to their inaccessibility. Bearing in mind the factors of climate, indigenous density, and accessibility, we find that the "europeanization of the world" has in fact proceeded along four different lines at different rates:

TABLE 1

PROPORTION OF AREA AND POPULATION LIVING IN AGRICULTURAL COUNTRIES, BY CONTINENTS

	Area (per cent)	Population (per cent)
World	74	76
Africa	100	100
Asia (excl. U.S.S.R.)	99	93
Central America and Caribbean	94	88
South America	79	77
Europe (excl. U.S.S.R.)	42	30
Oceania	7	16
U.S.A.-Canada	—	—
U.S.S.R.	100	100

[5] These computations, together with other research used for the present paper, were done under a grant from the Carnegie Corporation as part of a larger study of population and international relations. The assistance of Dr. Hilda Hertz, research associate in the Bureau's Division of Population Research, is gratefully acknowledged.


PEASANT-AGRICULTURAL
Countries with 50 Percent or more of Occupied Males in Agriculture
URBAN-INDUSTRIAL
Countries with less than 50 Percent of Occupied Males in Agriculture
EQUATORIAL SCALE
DISTRIBUTION OF THE WORLD'S PEASANT-AGRICULTURAL AND URBAN-INDUSTRIAL COUNTRIES
Period about, 1940-1948

MAP 1. Location of the World's agricultural countries and colonies, for dates between 1940 and 1948.

(A) *Temperate—Accessible—Vacant.*

In temperate areas accessible to trade but with sparse indigenous populations, the Europeans have tended to take possession of the land, to settle, and to grow in numbers by immigration and natural increase. Here industrialization has generally occurred and colonial political status has disappeared. Examples: Australia, New Zealand, Canada-U.S.A., and temperate South America.[6]

(B) *Tropical—Accessible—Vacant.*

In tropical and semi-tropical areas accessible to trade but with sparse native populations, the Europeans have tended to engage in estate agriculture, using imported African slaves or indentured Asiatics to supplement the scarce and unwilling native labor. Such areas have remained in a colonial status more frequently than the areas mentioned above and have failed to industrialize. Examples: West Indies, Malaya, and the Fiji Islands.[7]

(C) *Accessible—Occupied.*

In areas accessible to trade but with dense native populations, the Europeans have not settled in great numbers but have used political and economic dominance to gain their ends. The past success of native agriculture in such regions, nearly all of them tropical, is what enabled them to support dense populations and to ward off European settlement if not European control, and thus eventually to make a strong bid for independence. Examples: India, Ceylon, Java, and China.

(D) *Inaccessible—Vacant.*

In non-accessible and sparsely settled areas European penetration has been light, although colonial control or political annexation has been established and maintained. Since accessibility is a matter of degree, however, depending on the state of the technology, where the resources appear favorable this type of area is now being opened up and is facing potentially rapid development. One reason for inaccessibility has been the past inability of Europeans to cope with certain kinds of tropical conditions. Examples: New Guinea, much of tropical Africa, central South America and parts of the Netherlands Indies.

It follows from these four lines of European penetration that most of the tropical areas of the world, with a few exceptions, have remained in an agricultural stage. It follows also that most of them have until recently remained under outright political control or at least political and economic dominance. As of 1950 the relation between agriculturalism and outright dependence can be shown by the fact that only 1 per cent of the people in industrial areas were dependent, whereas 10 per cent of those in agricultural countries were so classed.[8] Expressing the matter differently, we find that 98 per cent of the population of dependent areas are in agricultural countries and only 2 per cent in industrial ones, whereas the figures are 75 and 25 per cent in the case of independent areas.

AGRICULTURAL DENSITY

With reference to population density, both the urban-industrial and the peasant-agricultural areas differ remarkably among themselves. Using a functional definition of density as the number of agriculturally employed males per square mile of agricultural land,[9] we find the highest figure in an industrial country—namely, Japan, which has a density of 410. On the other hand, the United States and Canada, also industrial, have

[6] Hawaii is an interesting case in this respect. At first tropical and relatively vacant it was so moderate in climate, and so accessible, fertile, and commercialized that its imported labor moved up in an expanding economy. As a result, the Islands now fall into the urban industrial group.

[7] It is of course realized that a given country or region may have parts which fall into different categories. For instance, the South in the United States had, prior to the Civil War, a substantial plantation development using slave labor.

[8] What is a "country" is not always easy to determine, especially as regards dependent areas. In general an area is counted as a separate dependent unit if it is not closely integrated into a wider dependent administrative unit. The ambiguity surrounding "independent" countries has to do mainly with those in the Russian orbit. Thus Rumania might well be regarded today as a dependent country. We have, however, counted as independent all countries where at least the fiction of sovereignty is maintained, although the Ukraine and other integral units of the Soviet Union are not so counted.

The Communist Bloc, including China, Northern Korea, and the Eastern zone of Germany, has 65 per cent of its occupied males in agriculture, the rest of the world only 57 per cent.

[9] Not the most refined measure of population pressure on agricultural resources, but one of the best that can be obtained for all countries. Where precise data allow, better measures are possible. See Wilbert E. Moore, *Economic demography of Eastern and Southern Europe*, chap. 2, Geneva, League of Nations, 1945.

As defined by us, "agricultural land" does not include permanent meadows and pastures, forests, or potentially arable land. At times this may lead to distortion—as in cases where ranching or nomadic herding is highly important—but it was thought better to keep a standard definition throughout.

an average of only 10 agriculturally employed males per square mile of agricultural soil. Similarly there is great variation between one agricultural country and another. In India-Pakistan, for example, the average farmer-farmland density is approximately 152 per square mile, whereas it is only 61 in Spain. In spite of this variation among both industrial and nonindustrial countries, the averages for the two types differ significantly. The industrial countries of the world have an average agricultural density of only 32 male farmers per square mile of farm land, whereas the agricultural countries have an average over three times as large—namely, 113 per square mile. This is what one would expect, since industrial countries usually practice a mechanized type of farming and hence need less manpower in relation to the land.[10] Table 2 shows that the more agricultural a country is, the higher its agricultural density tends to be. Table 3 shows that, as between the urban-industrial and peasant-agricultural countries, the difference in density tends to be consistent in direction within major continents or regions. The only exception is Asia, where only one country—Japan—represents the industrial category. Japan is interesting as showing that labor-intensive agriculture *can* be combined with modern industrialization. Japan started its industrialization on an intensive and densely settled agricultural base, whereas no other industrial country started with anything like such a high agricultural density.[11]

TABLE 2

AGRICULTURAL DENSITY ACCORDING TO DEGREE OF AGRICULTURALISM

Per cent of occupied males in agriculture	Agricultural males per square mile of agricultural land
0–29.9	18
30–49.9	55
50–69.9	73
70+	139

If three-fourths of the world's people still live in agricultural countries, how many of them live in countries of high agricultural density? From one point of view they nearly all do, for as we have just seen, the agricultural countries, which are poor, generally have a higher agricultural density than the industrial countries, which are rich. It comes as a shock, for example, to find that the rural countries of South America, the "empty" continent, have an agricultural density almost as great as the rural countries of Europe. To use the agricultural density in industrial areas as a yardstick, therefore, leads us to the true conclusion that most agricultural countries have too many people on the land. It is of some interest, however, to locate some of those agricultural countries which are above the average (113) in rural density. The following list gives the figures for selected countries of importance:

TABLE 3

AGRICULTURAL DENSITY BY CONTINENT AND TYPE OF COUNTRY*

	Agriculturally occupied males per square mile of agricultural land[a]		
	All countries	Urban-industrial countries[b]	Peasant-agricultural countries[b]
World	*88*	*32*	*113*
U.S.A.-Canada	10	10	[c]
Oceania	17	14	25
South America	57	16	101
U.S.S.R.	62	[c]	62
Africa	64	[c]	64
Europe (excl. U.S.S.R.)	74	69	79
Caribbean and Central America	128	85[d]	135
Asia (excl. U.S.S.R.)	182	410[e]	178

[a] Agricultural males are those gainfully occupied in farming, hunting, fishing, and forestry. Agricultural land is defined as including land under crops, lying fallow, and in orchards.

[b] Urban-industrial countries are those which have 0–49 per cent of their occupied males in agriculture; peasant-agricultural countries are those which have 50 or more per cent of their occupied males so engaged.

[c] No countries in the category. Africa has no industrial countries. If only the white population of South Africa were included, it would be defined as industrial; but most of the population is actually rural black.

[d] The only industrial country in Central and Caribbean America is Cuba.

[e] The only industrial country in Asia is Japan.

* Data on males gainfully occupied in agriculture taken mostly from censuses when available, from the United Nations *Demographic Yearbook* 1948, or from estimates made by the Bureau of Applied Social Research. Data on agricultural areas taken mostly from Food and Agriculture Organization *Yearbook of Food and Agricultural Statistics, 1948*, 1, *Production* (Washington, 1950), adjusted by the Bureau in some instances, or from estimates made by the Bureau.

[10] Colin Clark found that the output per head of males engaged in primary production varies inversely as the density of such males on farm land. See his *The economics of 1960*, chap. 4, London, Macmillan, 1944.

[11] If one assumes that Japan had in 1870 the same ratio of arable land to total area that she had in 1936, the number of people (both sexes, all ages, and all occupations) per square mile of arable land was approximately 1,500 which is higher than that in India today (about 600).

Egypt	382
Indo-China	322
Indonesia	302
Jamaica	297
Ceylon	282
Korea	279
China	260
Albania	220
Colombia	217
Peru	174
Puerto Rico	170
Ecuador	166
Thailand	153
India*	152
Union of South Africa	145
Mexico	138

* Including Pakistan.

The problem of acute agricultural density is primarily a problem of Eastern and Southern Asia, although it is also a major problem in the Caribbean and Middle American region. Table 4 shows the truth of this generalization.

Agricultural density throughout the globe shows a relationship to the different lines of "europeanization" mentioned above. The temperate regions accessible to trade but with sparse native populations (type "A"), regions which have been occupied by Europeans and rapidly industrialized, now show some of the lowest rural densities in the world. For instance, Australia and Canada-Newfoundland have only 11 male agriculturalists per square mile of farm land, the United States and Canada only 10. Agricultural settlement in these new countries is remarkably sparse when compared to the world average for industrial countries—32 male agriculturalists per square mile of agricultural land; or when compared to the average for European industrial countries—69.

The tropical and semi-tropical areas accessible to trade and with sparse native populations (type "B"), where Europeans have for long periods engaged in estate agriculture using imported African slave or Asiatic indentured labor and where therefore a now predominantly non-European population has largely replaced the original natives, show high but by no means the highest agricultural densities. The region that most typifies this type of settlement is the Caribbean. The whole Middle-American and Caribbean region has an average of 128 male farmers per square mile of agricultural land, but most of the islands have figures above this. For instance, Jamaica has a figure of 297; Puerto Rico, 170. What is interesting about this region, however, is that industrialization is beginning. Cuba has crossed the threshold of industrialization (by our 50-per-cent criterion), and consequently has a density figure of 81 only. Puerto Rico is on the verge of crossing the line, but shows some signs of moving in the direction of Japan with a high rural density combined with industry.

The highest agricultural densities are found in regions with teeming native populations where Europeans have not settled in great numbers (type "C"). To illustrate, China has something like 260 male farmers per square mile of farm land, Indo-China approximately 322, Ceylon 282, and India 152. Since most of these countries are located on the Asiatic continent and constitute the bulk of the Asian population, they explain Asia's continental average of 178—the highest

TABLE 4

AGRICULTURAL COUNTRIES: PROPORTION OF AREA AND POPULATION ABOVE OR BELOW WORLD AGRICULTURAL DENSITY[a]

Region	Area (per cent)	Population (per cent)
World		
Above	40	71
Below	60	29
Asia (excl. U.S.S.R.)		
Above	86	94
Below	14	6
America, Central and the Caribbean		
Above	93	90
Below	7	10
Africa		
Above	33	52
Below	67	48
America, South		
Above	25	28
Below	75	72
Europe		
Above	13	15
Below	87	85
Oceania		
Above	6	11
Below	94	89
U.S.S.R.		
Above[b]	—	—
Below	100	100
U.S.A.-Canada		
Above[b]	—	—
Below[b]	—	—

[a] The average agricultural density for the agricultural countries of the world is 113 gainfully occupied males per square mile of agricultural land.

[b] No countries in this category.

average for the non-industrial countries of any continent. Few of these countries are as yet anywhere near making the transition across the 50-per-cent-line. Japan alone has accomplished it; only Russia and Malaya approach it.[12]

The lowest agricultural densities, outside of the newly industrialized areas of European immigration, are found in the non-accessible and sparsely settled backward regions (type "D"). Not every country or colony in this category shows a low agricultural density. For instance, Kenya has an estimated 194 male cultivators to every square mile of agricultural land, and Tanganyika has 138.[13] Nevertheless, in most such areas the technology is so poor that not only is manpower the chief implement of work, but a fairly large area is required even for the sustenance of this manpower. The agricultural countries of Oceania, for example, have an average of 25 male agriculturalists per square mile of agricultural land. Africa, with an average of 64, compares favorably with the nonindustrial countries of Europe (average 79) and with the U.S.S.R. (62). As yet these type "D" areas are generally the most retarded of all, having been left that way because of their inaccessibility to markets or their deadliness. Yet because they have generally a small ratio between cultivated land and potentially useful land, and because they often have other unexploited resources, their prognosis for modernization may be more favorable than the other two types of agricultural country which have, as we have seen, crowded populations. If their untapped resources were quickly put to use, they could accomplish the industrial transition almost overnight, without building up a huge population. Heavy capitalization, mechanization of large-scale agriculture, and growth of industry, together with a shortage of labor, a ban on coolie immigration, and social opportunity for all classes (no race barriers) could not only bring in a moderate but important number of European immigrants with European fertility habits but could possibly change the fertility pattern of the natives within two generations. Such areas, when developed, would therefore have a chance of resembling Australia, New Zealand, and Argentina rather than Japan or India. At any rate, since relatively few people live in such areas at present, their current poverty does not pose the great human problems that the more crowded agricultural countries pose.

SOCIAL STRUCTURE OF CROWDED AGRICULTURALISM

The preceding analysis of agricultural densities in relation to the different modes of europeanization helps us to understand the currently high densities in particular areas. The problem of excess numbers is most acute in those parts of the world that were relatively well settled prior to European contact and were at the same time readily accessible to Europeans. It is also acute, but less so at present, in those areas in which Europeans carved out for themselves large landed estates, bringing in natives from other areas to replace or supplement the sparse indigenous population. In the first case, as observed in countries like China, Egypt, and India, there was, prior to European contact, a sufficient amount of farm technology, soil resources, and trade to support rather thick populations on the basis of traditional agriculture. But this agricultural civilization had its inherent limits. Organized on a village basis, with poor transportation and an oxcart technology, the surplus it produced was relatively small, hard to store and hard to distribute to famine areas. Some of the surplus was used, furthermore, to support relatively small groups at high levels of consumption, such as priests, soldiers, medicine men, and a ruling elite. Under such circumstances, in comparison with the present situation, only a moderate density was reached. Although the thickness of settlement in some fertile alluvial plains was greater

[12] Russia, of course, does not conform to type "C," as do most Asiatic countries. In part it is a European country to begin with and in part it has been colonized by European settlement in areas of sparse native population. According to 1939 estimates, Russia has slightly more than 50 per cent of her gainfully occupied males in agriculture, with an average of 62 of these males per square mile of agricultural land. Doubtless the country has now crossed the line into the industrial category, with the advantage of a density figure slightly below the European average and far below the Asiatic average.

Malaya, including both the Federation and the Crown Colony of Singapore, has according to the 1947 census, 52 per cent of its gainfully occupied males in agriculture, with a density figure of 110. It does not belong in type "C" but rather in type "B."

[13] Such areas, like industrial regions, show strikingly the difference between overall or average density and functional density. Tanganyika, for instance, is larger than France and the British Isles combined but has only about 7 million inhabitants. It is, therefore, sparsely settled in relation to its total area and resources, yet its *agricultural density* is quite high—about one person per acre under crops. Taeuber, Irene, *The population of Tanganyika*, 1, 43, Lake Success, United Nations, Population Division. 1949.

than anything human society had known before, it was far less than what can be widely found in modern times.

With the origin of industry in Western Europe and its spread to other areas of European settlement, the only densely peopled agricultural country outside of Europe to become industrialized was Japan. The others—mostly in Asia but also in North Africa—evolved a new mixed type of society based on contact with and political and economic subordination to the industrial peoples. Under this stimulus their agriculture became commercialized, more efficient, less diversified, and more individualistically controlled. The peasants were drawn willy nilly into a money economy, producing for a foreign market over which they had little control; the handicraftsmen were impoverished by the competition of cheap manufactures from foreign factories; the native leaders lost their control or became identified with the foreign masters as kept princes, landlords, and bureaucrats. The profits from this commercialized peasant agriculture were partly syphoned off by the industrial peoples and partly used by the local population to buy foreign manufactures, not to finance local industrial development. The native death rate was reduced through the control of famines, wars, and epidemics, but the birth rate remained static because, owing to the lack of industrial development, the people remained agricultural. The bulk of the native people became to a phenomenal degree a sort of rural proletariat, producing with its labor raw materials for the rest of the world but itself living at a very low level and not controlling the source of its income. The population did not grow as fast as it did in industrializing countries (some of which were industrializing on the basis of their colonies) but fast enough to add considerably to already heavy densities. In fact, the influence of colonial agriculturalism on population growth can be seen by the fact that some wholly new countries—such as Puerto Rico and Jamaica—soon also came to have a dense agricultural settlement, and in the countries of the oldest agriculture, new tracts were opened up for cultivation which soon reached densities the equal of the old tracts. In short, the countries not settled by Europeans but having either an already substantial native population or acquiring a population through the slave trade, indenture, and coolie migration had a commercial revolution thrust upon them but did not achieve an industrial revolution. Demographically, they wound up in the situation of having an industrial density with only an agricultural economy. Now their pressing problem is how to acquire the industry when numbers have already grown so large as to bankrupt the agricultural system which alone is their avenue to capital.

OLD VERSUS MIXED CULTURE

It is fashionable to say that the densely settled peoples of Asia have a variety of traditional cultures different from one another and different from that of the West, and that it is necessary to understand these cultures before one can understand the current predicament of the peoples in question. But while the initial premise is partially true, the conclusion does not fully follow. To a degree all of these overcrowded agricultural countries are alike. They are alike, in the first place, because the pre-industrial conditions of village farming made for a certain basic similarity in the traditional cultures themselves. All of the old cultures emphasized the family, kinship, and the joint household; all had some kind of village polity; all had a handicraft system; all took a religious and magical attitude toward the world; all gave women a position identified with home and children. It was these generalized traits, rather than the differences intriguing to the anthropologist, that determined the economic and demographic response to western contact. In terms of consequences the significant fact about traditional cultures was not so much the differences among themselves but the profound contrast between all of them and modern industrialism. And this leads us to the second cause of similarity among present-day agricultural peoples—namely, the fact that nearly all of them have been subjected to dominance and diffusion by industrial nations. Caste in India, familism in China, Mohammedanism in Egypt, communalism in Java—whatever differences these involved (and it is easy to exaggerate them) have been profoundly altered by western impact. The full force of this impact has been ably described by Furnivall.[14] Although the main nexus between the native and the European has been economic, Furnivall points out that economic behavior is in itself anarchic. It has to be subordinated to other ends by law and custom if there is to be an

[14] Furnivall, J. S., *Colonial policy and practice*, chap. 8, Cambridge, Univ. Press, 1948. See also his papers in Talbot, Phillips, (ed.), *South Asia in the world today*, Chicago, Univ. of Chicago Press, 1950.

ordered society, and so, once released by the European from the customary native controls, it could not be stopped, because the native could not under the circumstances absorb the whole European social system.

> . . . the West comes to the tropics as a liberator; it liberates the people both from the oppression of arbitrary personal authority, and from the burden of social abuses that the people have tolerated in the name of custom. Soon, however, there succeeds a second stage. So far as the people are released from customary inhibitions, economic forces are subject to no restraint but that of western law. In the West the law is an expression of social will, proceeding from the society itself and reinforcing custom, while adapting old customs to new circumstances. But in the tropics western law is imposed on society from outside, and, because it is not an expression of social will, it is powerless to restrain anti-social economic forces. These forces, liberated from the control of custom by the impact of the West, pursue their natural course, breaking down the social order, disintegrating native organic society into individual atoms, and, by thus depriving man of social protection against natural selfishness, operate more intensively, eliminating social values, and diffusing poverty.[15]

The village organization, with its restraints upon the use of land, quickly disintegrated. It no longer served as an intermediary between the individual and the state. The native leaders who naturally supported local cultural achievement by patronizing the arts, the priesthood, and the medical profession, were replaced by individuals, whether foreign or native, whose advantage lay in purely commercial activity. There was sometimes secondary colonization, as with the Indians in Fiji, Malaya, and Burma, or the Chinese in Malaya and the Netherlands Indies. Thus was created the plural society, with each ethnic group living in its own social world and dealing with the others only in economic terms. The native, often at the bottom of the scale, became increasingly caught in the pecuniary network, increasingly reduced to a standard pattern. The old division of labor was lost in the addiction to monoculture and the disappearance of handicrafts. Poverty came to be unrelieved by the former satisfactions of life. In short, the net effect of European contact upon most agricultural peoples has been social disintegration and a sort of progressive proletarianization of whole societies. The problems arising from such contact have been numerous and almost universal. Whether Dutch, British, French, or American contact reigned, there appeared the phenomena of minute subdivision of land, of landlordism and tenancy, of estates and estate labor, of undernourishment and malnutrition, of moneylenders and indebtedness, of village decay and lawlessness, of chronic underemployment, of monoculture, soil erosion, and low productivity. These common problems, as well as the common conditions of contact which have given rise to them, allow us to talk about the densely settled nonmechanized agricultural countries as a class. Differences between them there are, but they are not so much differences due to the traditional cultures as differences due to the time and extent of European influence.

The weakness of agricultural areas vis-a-vis industrial nations is inevitable. Either they cease to be peasant-agricultural or they continue to be dominated by urban-industrial nations. The superiority of industrial production, mechanized and highly capitalized, lies in the great multiplication it gives to human effort. It follows that almost *any* industrial country has a higher level of living than any agricultural country.[16] New Zealand, often cited as an agricultural country with an extremely high real income, actually has over half of its population in cities of 17,000 or above, and in 1936 only 27 per cent of its workers were employed in primary production. Its basic exports come from the land, but actual cultivation and herding are so highly capitalized that only a small portion of the total manpower is required to produce a surplus big enough to employ the rest in other activities.[17] One factor in New Zealand's ability to reach this envious position may well be its sparse population, a joint product of restriction of immigrants and low fertility, which are in turn a consequence of high standards of living and industrial achievement. The great dividing line between the rich and poor peoples of the earth is therefore not solely or even primarily population density, even when refined measures are used to gauge it, but rather the presence or absence of industrialization. The great agricultural densities in some of the peasant-agricultural countries are mainly important, not as an explanation of the existing poverty, but rather as an obstacle to the industrial transition. It seems easier to industrialize a

[15] Furnivall, *Colonial policy and practice*, 292–293.

[16] The only exceptions are those near the line on one side or the other, e.g., Japan vs. Hungary or Greece.

[17] Capitalization is illustrated by the fact that New Zealand has approximately 20 times as many miles of railroad per 1,000 population as India.

country such as Argentina or Brazil, where people are few in relation to resources, than to industrialize one like China or Egypt, where the reverse is the case. The great tragedy of colonialism was that it built up huge population densities without changing the economies from an agricultural to an industrial type.

The gap between industrial and agricultural countries can be illustrated in numerous ways, but two alone will suffice. (1) In 1939 the average per capita income for 30 countries that we have defined as agricultural was $76 per annum whereas in 22 industrial countries it was $287, or four times as great.[18] At the extremes, of course, the differences are much greater. (2) In the years around 1947 the average proportion illiterate aged 10 and over was 69 per cent in all countries having 50 per cent or more of gainfully occupied male workers in agriculture, whereas it was only 3.5 per cent in all countries having less than that proportion.[19] The great chasm separating the two kinds of society could scarcely be shown more clearly.

POLICY AND REALITY

If our findings are correct, the only means to higher levels of living in peasant countries is industrialization. The governments themselves realize this. Although an occasional Gandhi may wish to turn back the clock and retrieve the traditional culture, all governments now favor higher economic productivity. Any specific measure to increase the people's welfare must therefore be viewed from the standpoint of how it affects this master means.

POPULATION CONTROL

High on the list of conceivable measures is the control of population, because in many ways the pattern of dense settlement and prospective growth is a handicap to economic change.[20] Yet population control alone, without industrialization, would have little effect on the level of living. The difference in real income as between British Guiana and India, for example, is slight, despite the difference in overall population density. In other words, whatever effect the ratio of population to resources has on real income depends primarily on the state of the technology.

In the past the reduction of fertility has had to wait upon the growth of industry. It therefore appears strange to speak of lowered fertility as an initial aid to industrialization, and the prospect certainly appears unlikely. Yet, although the traditional cultures yielded a high birth rate[21] which has been maintained because they remained agricultural, the fertility pattern should not be regarded as inherently unmodifiable in the early stages of industrialization. As mentioned earlier, the traditional cultures have already been modified in many other respects; perhaps they can be modified with regard to fertility as well. Evidence is admittedly scarce, but the following points deserve consideration.[22]

(1) The technology of contraception may possibly be improved for peasant use. Little medical research has been devoted to contraception. With adequate attention, however, a scientific revolution in contraceptive technique might be accomplished which would ease the task of spreading birth control in backward areas. The popularity of sterilization in Puerto Rico suggests that

[18] Computed from *Point Four*, 113–114, Washington, U. S. Department of State, 1950. These averages are not weighted by population. If so weighted, the averages become $55 for agricultural countries and $358 for industrial countries. See also Piquet, Howard S., Point Four and world production, *Ann. Amer. Acad. Polit. and Soc. Sci.* 268: 150–151, 1950.

[19] Based on computations and estimates of literacy for the world's countries and colonies made by the Bureau of Applied Social Research. Urbanization does not differ so sharply. The agricultural countries had, in years about 1947, 11 per cent of their population living in cities of 20,000 or more, whereas the industrial countries had 39 per cent living in such places.

[20] Ghosh, D., *Pressure of population and economic efficiency in India*, New Delhi, Indian Council of World Affairs, 1946. Davis, K., The economic demography of India and Pakistan, *in* Talbot (ed.), *op. cit.*, 86–107. Perloff, Harvey S., *Puerto Rico's economic future*, part 3, Chicago, Univ. of Chicago Press, 1950.

[21] The birth rates, though high, have by no means been as high as was physically possible. Also, some primitive cultures have exhibited a rather low fertility. The Yap Islanders, for instance, have taboos, customs, and practices that severely limit births, and with the higher death rates brought by civilized contacts, their population declined sharply for many decades. See Peabody Museum Expedition to Yap Island, *The Micronesians of Yap and their depopulation*, mimeographed, Cambridge, Peabody Museum, Harvard Univ., 1948. A rather low fertility may have been a functional adaptation to a fairly low death rate in some primitive communities protected by isolation from infectious diseases. Agricultural civilizations, however, do not have this protection and consequently must have a high birth rate.

[22] For a fuller discussion of fertility prospects in an agricultural region, see the writer's book, *The population of India and Pakistan*, chap. 22, Princeton, Princeton Univ. Press, 1950.

a long-term contraceptive, if discovered, might prove more satisfactory than existing methods.

(2) Systematic interviewing and public opinion analysis have been insufficiently used for us to know the attitudes of peasant populations concerning limitation of offspring. One modern study in a rural section of India showed the following female answers to the question, "How many living children should a woman have when she is 40?" [23]

Number of Children	Frequency
0	3
1	110
2	353
3	353
4	299
5	102
6 and over	147

A modal preference for two or three living children suggests a desire among Indian peasants for small families.[24] It is also known that differential fertility exists in India as between city and country and as between literate and illiterate castes,[25] and that the fertility of certain highly placed groups is declining.[26] The pattern of lower fertility thus appears to be incipient. Further social research of a scientific character might reveal the latent resources that could be seized upon to undermine the present supports to high fertility.

(3) No all-out governmental campaign backed by every economic inducement, educational device, and technical assistance to diffuse contraception has ever been tried. We know that when birth control clinics have been set up in backward communities, the response has been discouraging.[27] We also know that in certain parts of Asia there has been some exposure to birth control propaganda. The reaction in these cases has apparently been mixed. Perhaps because the effort was not vigorous, the opposition was not vigorous either. It seems certain, however, that the present mixed culture in agricultural societies will not itself spontaneously evolve a widespread pattern of family limitation in advance of industrial change. The necessary all-out government-sponsored campaign, although it might conceivably have some effect, is not likely to be tried. Both in India and in Puerto Rico the government has taken a somewhat favorable attitude toward limitation of offspring,[28] but this is far from sponsoring an adequate campaign.

In a democracy, even when there is a latent private desire to limit offspring, it is difficult for a government deliberately to set about altering the institutions and attitudes that give high fertility (viz., early and universal marriage, restriction of women to the home, dependence of female esteem upon male offspring, the economic use of children at an early age, and the adoption of a religio-magical approach to reproduction). These social factors are changing gradually,[29] but more as a reaction to incipient industrialization and urbanization than as a response to a deliberate public policy in advance of these developments.

A totalitarian government is less restricted by the predilections of the people, but in the past such governments have not felt that a general reduction in fertility would give more industrial and military power to the state. To eliminate undesired populations they have tended to rely upon increased mortality rather than lowered fertility. It is too early yet to know what will happen in this matter to the new colonies controlled by a totalitarian state, but it may turn out that the dominant power will have no more interest in the local standard of living than did the old seats of empire.[30]

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[23] Sekar, C. Chandra, and Mukta Sen, Enquiry into the reproductive patterns of Bengali women, Indian Research Fund Association and All India Institute of Public Health, not yet published. The sample of rural women was obtained in Bengal, about 20 miles from Calcutta.

[24] Similar findings have been obtained in Puerto Rico in a study directed by the writer and now being analyzed by Paul K. Hatt, who was in charge of the field work.

[25] Davis, Kingsley, Human fertility in India, *Amer. Jour. Sociol.* **52**: 243–254, 1946.

[26] Sekar, C. Chandra, Some aspects of Parsi demography, *Human Biology* **20**: 47–89, 1948.

[27] Beebe, Gilbert W., *Contraception and fertility in the southern Appalachians*, Baltimore, Williams & Wilkins, 1942. Also Beebe and Jose S. Belaval, Fertility and contraception in Puerto Rico, *Puerto Rico Jour. Pub. Health and Trop. Med.*, **18**: 3–52, 1942.

[28] National Planning Committee, Sub-Committee on Population, *Population*, 22, 30–31, 53, 77–78, 81, Bombay, Vora, 1949. Perloff, *op. cit.*, 229–235.

[29] In both India and China the age at marriage is apparently rising and women are being increasingly employed away from the home. On China, see Levy, *op. cit.*, 299–302, 309–313, 323–324.

[30] For an excellent description of what is here called "totalitarian colonialism," see Yakobson, Sergius, Soviet concepts of Point Four, *Annals Amer. Acad. Pol. and Soc. Sci.* **268**: 129–139, 1950. The success of such colonialism in achieving economic development is shown by Warren Wilhelm, Soviet Central Asia: Development of a backward area, *Foreign Policy Repts.*, **25**: 218–228, 1950.

ACCELERATED MODERNIZATION

Whatever the policy toward fertility, other means of facilitating industrialization are required. The probable population growth in agricultural countries makes the speed and character of these measures crucial. The faster the rate of modernization, other things equal, the quicker will be the response of fertility, the earlier the end to population growth, the smaller the ultimate population reached, and the higher the eventual level of living. These effects will be even greater if, in the process of rapid industrialization, those elements of modernization known to depress fertility are emphasized, such as education, urbanization, geographical and class mobility, multi-family dwellings, commercial recreation, and female employment.[31] Since such measures also facilitate industrialization, there is no necessary conflict between them and rapid economic development.

The means required to accelerate industrialization, however, are so disruptive to the existing social order that the people and the vested interests tend to resist them.[32] Furthermore, the requisite economic controls are so complex that most agricultural states do not have the administrative machinery, technical competence, and public knowledge to carry them out with entire success.[33] Weak governments therefore find difficulty in carrying out obviously necessary measures, and outsiders are limited in what they can do for them, by the identification of nationalism with the existing social structure and with economic autarchy.

Unfortunately, the weakness of agriculturalism that led to its previous colonial servitude still persists. At the very moment when rural nations have finally won their independence under one kind of world system, nationalism strong in sentiment but weak in practice is showing signs of proving unworkable under an emerging new kind of world system. Nominal political independence is not today, and has never been, a guarantee of industrial development.

Despite these difficulties, agricultural nations will doubtless industrialize eventually. Short of permanent world catastrophe, the new stage of cultural evolution will complete its diffusion. That it is continuing to spread is shown by the fact that virtually everywhere the literate and urban population is growing faster than the illiterate and rural, public health is improving, and village isolation is breaking down. The question is not whether industrial society will spread to all the world, but how soon and under what circumstances.

Particular conditions will govern modernization in different countries. Some may make a relatively smooth transition without major conflicts; others have such heavy obstacles that a smooth transition seems utopian. In the latter case the efforts made by native governments and by international agencies and friendly nations may prove too gentle to accomplish rapid industrialization, despite the tremendous resources that could be brought to bear. If this proves to be the case, if the status quo is allowed to obstruct and dissipate the effort, then such nations will remain too weak to prevent turmoil. They will either gain strength through internal revolution or be conquered by some new totalitarian colonialism of the right or left.[34] In either case the sweeping away of old barriers may provide a chance for mechanized agriculture and industry to come speedily, although not in the institutional forms familiar to us. Whether or not communist or fascist industrialism will bring the same demographic reactions as occurred under liberal capitalist industrialism cannot be predicted with certainty, but there are reasons to think it will. Even if totalitarianism should view a growth of numbers as advantageous, an increasing population would eventually prove self-defeating. Furthermore, a condition of demographic glut can be written off in a fairly short time by a sudden increase in mortality—an increase that need not necessarily retard industrial development commensurately. Possibly a world strug-

[31] The social accompaniments of modernization have been well summarized by Levy, *op. cit.*, part 3. See also Moore, Wilbert E., Utilization of human resources through industrialization, *Milbank Mem. Fund Quart.*, **28**: 52–67, 1950.

[32] Hoskins, Halford L., Point Four with reference to the Middle East, *Annals Amer. Acad. Pol. and Soc. Sci.* **268**: 88–94, 1950. Davis, Economic demography of India and Pakistan, *loc. cit.*, 41–42.

[33] A fact frequently mentioned in the United Nations *Economic survey of Asia and the Far East* 1948, Lake Success, U. N. Department of Economic Affairs, 1949.

[34] For an excellent analysis of sources of instability in India see Thorner, Daniel, Problems of economic development in India, *Annals Amer. Acad. Pol. and Soc. Sci.* **268**: 96–103, 1950; also, his, Prospects for economic development in Southern Asia, *Foreign Policy Repts.* **26**: 18–28, 1950.

gle several times more deadly than the last will be the cataclysm that will give agricultural nations a demographic breathing spell and a stimulus to such social change as will make future population pressure unlikely. At any rate the present situation in crowded agricultural nations cannot be regarded as anything but a temporary stage in the world transformation from illiterate agriculturalism to literate industrialism. Both the ascription of hopelessness to the situation and the opposite view of the world's resources and human science as capable of providing for a population of any size may reflect our natural desire to eliminate war, strife, and suffering from the process of social change. The actual course of events, however, may not respect this desire.

ECONOMIC FACTORS IN THE DEVELOPMENT OF DENSELY POPULATED AREAS

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Without frugality none can be rich, and
with it very few would be poor.[1]

INDUSTRIALIZATION, as defined in this paper, comprehends the sum total of the factors that have made and will continue to make for increase in net output per worker and/or per capita.[2] Because of limitations of space, however, and because our predominant concern is with the economic determinants of industrialization, we shall deal fully only with some of the circumstances governing industrial progress. Our treatment has been organized under seven heads, to each of which a section is devoted: I, the determinants of industrialization; II, strategy in the industrializing of under-developed countries; III, the role of material equipment in industrialization; IV, industrial development and industrial composition; V, the evolution of the labor force; VI, exchange relations and international disparities in income; VII, historical illustrations and future prospects.

While this paper treats of the industrialization of under-developed countries, it is concerned primarily with that of countries marked by pressure of population, lowness of average income, and concentration of the labor force in agriculture and forestry. For purposes of comparison and completeness of presentation, however, considerable attention will be given to under-developed countries where, though income is low and agriculture predominates, population pressure is not so marked. In this latter category fall most countries of Latin America, Africa exclusive of parts of North Africa, and Oceania. In the former category fall most countries of Asia and North Africa, together with the principal islands situated in the Caribbean area. We shall touch only cursorily upon the remaining relatively under-developed parts of the world, namely, Southern and Eastern Europe and Soviet Russia. Accordingly, while we shall not deal with all the world's under-developed economies (which embrace close to four-fifths of the world's population but get somewhat less than three-tenths of the world's output of goods and services), we shall treat of most of those within which reside that part of the world's population—more than one-half—which is still living in the neighborhood of the bare subsistence level.[3]

While the cultures of the peoples living in densely populated under-developed countries usually are more ancient and more imbedded in the social structure than are the cultures of the less densely populated under-developed countries, both sets of countries share many conditions in common. Evidence for this is provided in tables 1–3, presented at the close of this paper. Agriculture is the predominant occupation. Both within and outside agriculture workers are poorly supplied with relevant forms of productive equipment such as cultivatable land, machinery, and other forms of fixed and working capital. Education and industrial training are lacking, with something like three-fourths of the population

[1] Johnson, Samuel, *The Rambler*, No. 57.

[2] Our approach to industrialization emphasizes not so much its cultural and economic consequences as its nature, viz., a complex of interrelated processes governing the level and movement of output. On the definition of industrialization see Kuznets, S., An outline of a comparative study of industrialization, in *Problems in the study of growth*, N. Y., National Bureau of Economic Research, 1949; also Chang, P. K., *Agriculture and industrialization*, chap. 3, Cambridge, Harvard Press, 1949.

[3] Two decades ago more than half the world's population was producing an income insufficient for subsistence, while in 1947 the per capita income of more than half the world's population was below, often appreciably below, $100. See Clark, Collin, *The conditions of economic progress*, 53, London, Macmillan, 1940, and *The economics of 1960*, appendix, London, Macmillan, 1942; United Nations, *Technical assistance for economic development*, 4, Lake Success, United Nations, 1949. For corroborating evidence see tables 1 and 2 at the close of this paper; also tables 3–4 which indicate how lowness of money income is translated into lowness of consumption in respect of food, textiles, transportation, steel, and other significant items.

illiterate and with technological knowledge restricted in quantity and confined to a few. Fiscal, financial, and related institutions and practices are primitive and defective, in terms of Western standards. Nutrition is quantitatively and qualitatively inadequate. Disease is widespread, mortality is high in most age brackets, and expectation of life at birth is low. Natality, together with potential natural increase, is high with the result that improvements in mortality normally are accompanied by corresponding increments in the rate of population growth. In consequence of these and other circumstances, per capita incomes are very low.

I. DETERMINANTS OF INDUSTRIALIZATION AND NET OUTPUT PER CAPITA

Progress in industrialization, howsoever defined, is intimately associated with that of per capita net output (= net income).[4] If industrialization is broadly defined, its determinants tend to coincide with those governing the movement of per capita income. If industrialization is more narrowly defined, its progress both conditions and is conditioned by that of per capita income. Finally and irrespective of the manner in which industrialization is defined, what constitutes its most appropriate tempo is determinable only in the context of the conception of income assumed to rule, involving, as it does, questions of income distribution and use, consumer sovereignty, and consumer freedom of choice.

It should be noted that some of the aggregates used in this paper, together with the averages based thereon, are subject to various limitations. First of all, data relating to income production and use and to capital equipment in most of the under-developed countries are quantitatively and qualitatively defective and ridden with conjecture. Second, the aggregates and averages employed are subject to those limitations to which all aggregates of incommensurable elements are subject. These limitations are intensified when the aggregates are compared in time and space, for the introduction of the cultural differences associated with differences in space and time accentuates the difficulties arising out of incommensurability as such. Finally and even more difficult is the assessment of the meaning of these diverse and changing aggregates when expressed in terms of subjective, or psycho-physiological, welfare. Fortunately, the validity of most of our findings appears to be largely independent of the difficulties mentioned.[5]

The movement of net output per capita has many determinants, most of which directly govern the progress of industrialization even when this process is narrowly defined. Few if any of these determinants are completely independent, each being connected, as a rule, with one or more of the others. In fact, each of the societies of which we treat may be looked upon as a loosely integrated but essentially distinct cultural whole that is required, upon being exposed to the forces of industrialization, to accommodate itself to these forces and absorb their effects. For this reason the progress of industrialization, while in large measure the same in all societies, varies from society to society. Even so, the determinants of industrialization, though physically inseparable, are analytically and empirically distinguishable from one another.

We present below a list of twenty determinants of the progress of industrialization, sixteen of which govern its movement directly and four of which affect its movement indirectly through the medium of income and related changes. Some of these determinants are described at this point. Others are merely listed, since they are treated below. While all of these determinants affect the course of industrialization in a closed or a world-wide economy, some lose much of their significance when the economy to which they relate is an open component of the world-wide economy, for under these circumstances the economy in question can draw upon other economies in respect of the determinant under consideration. The sixteen determinants that directly affect the course of industrialization follow:

1. Material equipment (i.e., productive machinery, utilizable land, natural resources, and other forms of

[4] In this paper the terms net output and income are used interchangeably as measures of productive effectiveness. On the technical aspects of national income measurement see Shoup, Carl S., *Principles of national income analysis*, New York, Houghton Mifflin, 1947; and League of Nations, *Measurement of national income and the construction of social accounts*, Geneva, United Nations, 1947.

[5] Some of the difficulties referred to have been treated by Samuelson, Paul A., Evaluation of Real National Income, *Oxford Econ. Papers* 2: 1–29, 1950; Little, I.M.D., The foundation of welfare economics, *ibid.* 1: 227-246, 1949; Arrow, Kenneth J., *Social choice and individual values*, Chicago, Cowles Commission Discussion Paper (Economics: No. 258), 1949; Bergson, A., Socialist economics, in Ellis, H. S., ed., *A survey of contemporary economic theory*, 412–418, Phila., Blakiston, 1948.

"capital") per worker. This determinant is conditioned by the rates of saving, capital formation, and population growth.

2. The state of health of the population.

3. The exchange relations obtaining between the economy under analysis and other economies.

4. State of the industrial arts. Hereunder may be included the level of applied technological and related knowledge and practice, together with the extent to which this knowledge is diffused throughout the population. The occupational composition of a country's labor force reflects, as do other rough indices, the level of applied and applicable knowledge. In general, the more varied and the more differentiated the nonprofessional component of the labor force, the more advanced is the state of a country's industrial arts. This being the case, questions relating to the occupational composition of a country's labor force are in essence questions relating more fundamentally to the state of that country's industrial arts.

5. The educational, the scientific, and the related cultural equipment of the population. Hereunder should be included all basic and facilitating information (i.e., knowledge that resembles "seed corn" rather than mere engineering "knowhow" which is included under [4]), together with the elements that govern the accumulation and dissemination of such information. Inasmuch as institutional and other circumstances invariably cause the level of *applied* knowledge to fall short of the level of *available* knowledge, the state of the industrial arts almost always may be improved somewhat even though determinant (5) remains unchanged. Ultimately, however, the progress of (4) is restricted by that of (5).

6. Dominant character of the politico-economic system. Such a system may be free-enterprise, mixed or dual, social-democratic, or "totalitarian" in character, with the result that the role of the state in economic affairs may vary greatly. Presumably, since these systems differ in the effects they exercise upon consumer sovereignty, capital formation, "incentive," and the accumulation and diffusion of technological and related knowledge, they must differ in their aggregate effects upon the rate of industrialization.

7. The relative magnitude of that part of the population which is adept at making entrepreneurial and innovational decisions, together with the location and the distribution of the power to make and execute such decisions. For industrial progress is markedly dependent upon (*a*) the relative number of imaginative and energetic innovators and entrepreneurs present in the population, (*b*) the extent to which these qualified persons are empowered to make and execute relevant decisions, and (*c*) the degree to which these individuals are free of hampering legal and institutional arrangements. In the past this distribution has been most favorable in countries possessing a comparatively strong "middle class" that enjoyed sufficient support at the hands of the state; while countries lacking a sufficiently strong middle class have had to depend upon the state to provide entrepreneurial leadership in so far as possible.

8. The distribution of workers among occupations and the relative amount of unemployment (complete, partial, or disguised) present in the economy. An individual is completely unemployed if he is an unengaged job-seeker, or if, given accepted standards, he ought to be enrolled in the labor force. An individual is partially unemployed if he is engaged for less than the normal work period. An individual is describable as disguisedly unemployed if he is so engaged that he produces less than he could produce in other employments which he is able and disposed to enter. As will be noted later, agriculture is the main repository of the disguisedly unemployed. It may be said that, other things equal, the presence of unemployed workers facilitates industrialization, while their employment augments output.

9. Make-up of the prevailing value-system. Most important of the elements of such a value system for our analysis are: (*a*) the values which animate economic, political, and social leaders; and (*b*) the values which significantly affect economic creativity and the disposition of man to put forth economically productive effort. The values included under (*a*) are unfavorable to material progress in proportion as they stress immaterial instruments and ends, or as they sanction the attainment of income and wealth through exploitation as distinguished from the organization and management of resources in a manner suited to serve mass demands. The values included under (*b*) relate to the content of the aspiration levels of representative individuals. If these levels include material objectives which, though not achievable with ease, may be won through the exercise of appreciable effort, representative individuals will be disposed to be industrious and creative.

10. Effectiveness and stability of the rules, institutions, and legal arrangements designed to preserve economic, political, and civil order. Stability and order are prerequisite to progress in both industrialization and income. Where these conditions are not met, the time horizon is necessarily short, capital formation is retarded, and the disposition to undertake ventures is greatly reduced. Industrialization is bound to proceed slowly at best, therefore, so long as stability and order are lacking in fact and in prospect.

11. Degree of cooperation and amity obtaining between the groups and classes composing the population. So long as such cooperation and amity are not sufficiently present, and their lack is not made up by a strong government capable of exercising compensatory force, determinants (10) and possibly (9) will be adversely affected, and progress in industrialization and income will be influenced accordingly. Determinant (11) appears to be of considerable significance,

therefore, in many of the countries here under consideration.

12. Flexibility of the institutional structure and the physical apparatus of the economy. Flexibility permits an economy to adapt to changes that are unforeseen and thereby operates both to accelerate the rate of change and to increase the effectiveness with which income-increasing changes are taken advantage of.[6] In proportion as an economy is inflexible, these fruitful accommodations are not attainable. Accordingly, since income and industrial progress entail change that is both saltatory and in part unpredictable, flexibility is essential to industrialization. In some of the countries here under analysis, inflexibility appears to offer great resistance to industrialization in its early stages.

13. Relative amount of vertical and horizontal mobility characteristic of a population. Per capita net output is at a maximum in a population when, *ceteris paribus*, it is making optimum use of the productive resources at its disposal; and a population is making such use of its resources when, with the marginal social benefit of every product equal to its marginal social cost, the value of the marginal product of each factor of production is equal to its price in all uses. Furthermore, as circumstances affecting production change, per capita output will move to the new maximum consistent with such changes, so long as the conditions of optimum resource use are met. These conditions can be met only if a population is sufficiently mobile, and able and disposed to modify its geographical, occupational, and related distributions. For industrialization and other sources of income-affecting change entail a continual redistribution of human productive agents in space and among employments, old and new. Determinant (13), therefore, resembles (12) in that the former reflects the flexibility of the population as such, whereas the latter reflects the flexibility of the population's institutional and physical equipment. Mobility, like flexibility, appears to be much less characteristic of nonindustrialized than of industrial populations.

14. Degree to which a population's pattern of consumption is adjusted to its pattern of resource-equipment. Some adjustment along these lines is always found, since that which is relatively abundant commands relatively low prices, and that which commands relatively low prices tends to be substituted in some part for that which commands relatively high prices. Even so, however, adjustment is never complete, and progress in income and capital formation is less than it might be. This proposition appears to hold in some measure for the countries with which we are concerned.

15. Internal geographical distribution of economic activities. Other conditions remaining the same, per capita net output will be greater or less in proportion as economic activities are well or badly distributed in space. The distribution of economic activities in space is highly significant also for an economy's progress in industrialization: (*a*), indirectly, because the progress of industrialization is positively associated with the already existing level of per capita output; and (*b*), directly, because the better situated a new industry-increasing venture is in space, the more likely it is to succeed and thus further the industrialization process.

16. The structure of that part of the institutional framework which touches immediately upon economic activities, together with the manner in which this structure functions. Among the institutions of most relevance here are those having to do with money, banking, taxation, etc., and those bearing upon primary, secondary, and technical education.

The sixteen determinants just enumerated and/or described condition industrialization directly. A number of factors, themselves concomitants of industrialization, affect its course indirectly in consequence of their direct influence upon the movement of per capita income. The most important of these factors are the following.

A. Degree of specialization and division of labor in effect. If industrialization does not proceed compatibly with specialization and division of labor, the extent of the market being given, it affects the level of output less favorably than it otherwise might.

B. Scale of economic organization and activity prevalent. Hereunder are included those sources of economy in operation consequent upon increase in scale which do not properly fall under (A).

C. Age composition of the population. Per capita output is governed, *ceteris paribus*, by the ratio of persons of productive age (say 15–64, 20–69, etc.) to the total population. This ratio rises when gross reproduction begins to fall and when expectation of life at birth increases (provided that enough of the increment of increase is situated within the productive age range). Changes in age composition in England and Wales between 1875 and 1935 increased potential productivity per male about 22 per cent. Substitution of the age composition of the United

[6] Because of man's inability to eliminate economic and other relevant forms of uncertainty, and his associated incapacity to predict the relevant course of events, it is essential that he give great weight to the retention of flexibility. This proposition holds in respect of matters ranging from the construction of plants and cities to the formulation of general policies at the economic and the political levels. What is the appropriate amount of flexibility is, of course, a matter of judgment and therefore itself permeated by uncertainty, particularly since increments in flexibility usually entail short-run decrements in output, etc. When A. J. Toynbee implies that caste and specialization are responsible in large measure for the arrest of civilizations, he is arguing, in effect, that failure to retain flexibility has been primarily responsible for the interruption of the progress of diverse societies. See his *A study of history* **3**: 79–111, London, Oxford Press, 1935.

States and Canada for that of the populations of Africa, Asia, and Latin America would increase potential per capita productivity in these regions by about one-sixth.[7] Improvements in age composition make necessary a somewhat higher increment in capital than would otherwise be required.

D. Biological composition of the population. Any change in the genetical composition of a population that increases (decreases) the relative frequency of individuals with supra-average potentialities operates to increase (decrease) per capita productive capacity. This determinant operates more slowly than most and may, therefore, be disregarded if the time span under analysis is short. Several inferences may be made in respect of changes in biological composition, however. (*a*) With the progress of a society in industrialization, its relative requirement of superior individuals increases and its relative capacity for making use of inferior individuals decreases. Industrialization may be said, therefore, to call for improvement in a population's biological composition. (*b*) An increase in the relative number of superior persons produces two effects analogous to substitution and income effects: (i) the relative rate of imputed productivity of the superior persons tends to fall; (ii) aggregate national income rises, usually enough to permit an increase in the absolute amount of income imputable to superior persons despite the kind of adverse substitution effect described under (i).

Industrialization tends to be accompanied by improvements in (A) and (B). Industrialization may be accompanied in the longer run by income-increasing improvements in the age composition of the population, provided that both the birth rate and the death rate move downward as a result of industrialization. If only mortality in the lowest age groups responds significantly to industrialization, the relative number of persons of working age may be reduced somewhat. In the past industrialization has been accompanied, but only gradually, by a decline in gross and net reproduction and by improvement in age composition.

Should the preceding list of determinants of industrialization and per capita income be deemed incomplete, a residual category may be added to comprehend factors that at present appear to be insignificant.

[7] These estimates are based upon United Nations, *World population trends*, 14–17, Lake Success, United Nations, 1949. See table 1, line 3, at the close of this paper. The effect of changes in age composition is conditioned, of course, by occupation, year of entry into and withdrawal from labor force, etc. See on age composition and output New York State Joint Legislative Committee on Problems of the Aging, *Birthdays don't count* (Legislative Document No. 61), Newburgh, 1948; Durand, John D., *The Labor force in the United States 1890–1960*, N. Y., Social Science Research Council, 1948.

II. THE STRATEGY OF INDUSTRIALIZATION IN UNDER-DEVELOPED COUNTRIES

Contemporary interest in the industrialization of under-developed countries is premised upon the supposition that the process of industrialization can be accelerated through appropriate intervention at strategic points in comparatively non-industrialized economies. Intervention, it is assumed, may flow from two sources, from powerful interest groups and from the apparatus of state in the non-industrialized country, and from other countries already industrialized. It is inferred that the rate of industrialization in non-industrialized countries may be elevated above that observed in the past in countries presently industrialized because: (*a*) the retarded countries may draw upon the experience, knowledge, and material and human resources of industrialized countries; and (*b*) the state may assume a much larger and more effective role in industrialization than it assumed in Northern and Western Europe and the English-speaking world prior to World War I. Let us therefore consider the strategic aspects of industrialization.

The progress of industrialization is most likely to be maximized if action is exerted simultaneously upon many of the determinants of industrialization, and not merely upon one at a time. For while industrialization is a cumulative process, an improvement in any one determinant being propagated to others and becoming the occasion of their improvement, the fundamental relation obtaining among the determinants is one of complementarity, with the effects consequent upon the improvement of any one determinant being definitely limited by what is independently taking place in respect of other determinants. It should be added that industrialization, while always susceptible of cyclical retrogression, does not appear subject to secular decumulation subsequently to its having obtained an effective foothold in an economy, presumably because the determinants of industrialization become immune to adverse change beyond a limited amount.

Strategy requires that action be exerted upon those determinants of industrialization which are relatively most responsive to action, since it is assumed that the remaining determinants will in time undergo appropriate modification in consequence of the changes that have been produced in

the more responsive of these determinants. The determinants may be classified, therefore, into those which are likely to be responsive to action from abroad and those which are likely to be amenable to action from within.

In the category of determinants responsive to external action fall (1)–(5) and (16). For a non-industrialized country can draw, but only within quite circumscribed limits, upon industrialized countries for equipment, for assistance in respect of public health, industrial "know-how," and scientific information, and for guidance regarding the establishment of a salutary institutional structure. These six determinants, together with (10), also appear to be the ones most susceptible to action from within, a matter of importance in view of the fact that the amount of assistance obtainable from abroad is limited both by the shortage of foreign personnel and material equipment and by the fact that the annual capacity of a non-industrialized country to absorb such personnel and equipment is restricted. Determinants (6), (9), (C), and (D) appear to be comparatively immune to direct action from within or without. The remaining determinants, while susceptible of little or no direct influence from abroad, appear to be somewhat subject to such influence from within. In this category fall determinants (7) and (8), (11)–(15), and (A) and (B), with (7) and (8) perhaps the most susceptible.

If the preceding analysis is correct, it follows that action from abroad should be concentrated upon determinants (1)–(5) and (16) and that action from within should be taken principally in respect of (1)–(5), (10), and (16). Some action may be exerted upon (7) and (8) and a lesser amount upon (11)–(15) and (A) and (B). No action is indicated in respect of (6), (9), (C), and (D). It may be assumed that the determinants which are largely or wholly unresponsive to direct action from within and/or without will of necessity undergo modification in consequence of the changes that are produced in the determinants responsive to action from without and/or within.

III. MATERIAL EQUIPMENT PER CAPITA: ITS EFFECTS AND ITS SOURCES

The most important of the tangible factors that govern the level of per capita output and condition the rate of industrial progress is the availability of material equipment in its various guises. Most inventions and innovations, even though they be capital-saving on the balance and in the longer run, must be incorporated materially before they can enlarge man's productive powers. Furthermore, it is largely in virtue of the average amount of appropriate equipment at the disposal of workers that average output per worker is high in an economy, since then (within limits) more equipment can be used per worker in given industries and relatively more workers can engage in industries in which both equipment and output per worker are high. Finally, of the relatively mutable determinants of industrialization, none is potentially more responsive to concrete and salutary action from within and without an economy than is the stock of equipment, for its amount is significantly augmentable while the number of its users may be restricted through the employment of effective means of birth and immigration control. In this section we shall (*a*) present in summary form information relating to the income-producing effects of material equipment and (*b*) indicate how rapidly per capita income may be raised through the augmentation of the stock of material equipment.

Data relating to material equipment per worker by country are quantitatively and qualitatively unsatisfactory in respect of most parts of the world, and above all in respect of the underindustrialized parts of the world. The attainment of satisfactory international comparisons is rendered difficult, moreover, by the fact that information may be available only for some forms of material and not for all. For example, information may be available for "arable land" but not for such non-landed capital (working capital and fixed capital) as is employed in agriculture along with land. It may be assumed, however, that although the composition of fixed capital and the ratio of working capital to fixed capital vary by country and industry, the dominant relation obtaining among the major forms of capital is complementary rather than competitive in character. For example, the amount of non-landed and working capital utilized per worker in agriculture tends to vary in the same direction, although not in the same measure, as does the amount of land cultivated per worker.[8] It may be inferred, therefore, that, if we have data relating to a significant amount of the equipment used per worker by country, we have a fairly representative sample of the international differences in equipment per worker that actually obtain.

[8] See Black, J. D., Agricultural population in relation to agricultural resources, *Annals Amer. Acad. Polit. and Soc. Sci.* 188: 211, table 3, 1936; Mandelbaum, K., *The industrialization of backward areas*, 95, Oxford, Blackwell, 1945.

(*a*) We present data relating to equipment and output per worker in tables 1–2 and 4. These data suggest that lack of equipment is a dominant characteristic of non-industrialized countries and that the principal immediate cause of mass poverty in most parts of the world is the lack of an adequate supply of effective and productive equipment.

Output per worker in agriculture is closely associated with the various forms of equipment, such as land and energy, at his disposal. Clark finds production per farm worker to vary inversely with the square root of the number of male workers per 1,000 hectares of farm land. Essentially the same relationship is found when farm land has been converted into more standard units. Output responds significantly also to nonhuman energy inputs.[9] As we have indicated, while other forms of capital may be substituted for land, the relationship obtaining between land and the various forms of agricultural capital usually is complementary rather than substitutive. Hence it is aggregate investment per agricultural worker that is important. In the United States in 1929, for example, net output per farm worker appears to have increased somewhat more than $100 for each increment of $1,000 in the amount of agricultural property being used per farm worker. In the late 1930's a somewhat similar relationship obtained.[10]

Outside agriculture and in economies as wholes, relationships similar to those just described also obtain. The role of land, of course, is much less mportant, since land forms a much smaller fraction of a worker's equipment outside agriculture and in economies as wholes than in agriculture. The role of nonhuman energy is extremely important outside as well as inside agriculture, an increment in the amount of energy available per worker tending to add a sizeable increment to his output. Comparison of line 10 with lines 4–6 in table 1 reveals the importance of energy; so also does comparison of column 8 with columns 4–6 in table 2. The role of energy may be illustrated even more strikingly through the use of production functions designed to disclose the quantitative relationship obtaining between increments in energy and increments in income.[11] It is because the role of energy in current productive operations is so great that it may be said that whether or not an economy has a real industrial future turns largely on whether it has abundant reserves of energy-containing resources (e.g., see column 9 in table 2 and line 11 in table 4).

The importance of capital equipment is on a par with that of energy. Among the reasons for this is the fact that in large measure equipment per worker is an index of energy available per worker, since the inventions, etc., incorporated in the capital equipment put energy at the worker's disposal. The importance of capital is suggested by the correlation obtaining in tables 1 and 2

[9] On the relation of farm land to output per worker in agriculture see Clark, *Economics of 1960*, 34–36, and The productivity of primary industry, *Rev. Econ. Progress* 1: 5–6, 1949. A Spearman rank correlation of 0.95 obtains, for 8 countries, between output per male farm worker (as estimated by Clark in *ibid.*) and crop land per member of the farm population (as estimated by the FAO *Mission For Greece*, 155, Washington, FAO, 1947). Between output per male farm worker (as estimated by Clark) and energy consumption per person engaged in agriculture (as reported in N. B. Guyol, *Energy resources of the world*, 7, Washington, U. S. Dept. of State, 1949) a Spearman rank correlation of 0.87 obtains. Line 8 of table 4 indicates that in the non-industrialized parts of the world the tractorization of agriculture has made only insignificant progress.

[10] These estimates are based upon Black, *op. cit.*, 211–212. On the late 1930's see Johnson, D. G., *Forward prices for agriculture*, chap. 7, Chicago, Univ. of Chicago Press, 1947.

[11] While international differences in output per farm worker are significantly associated with international differences in arable land per farm worker, international differences in land per worker are not significantly associated with output per worker, in part because land varies in quality but principally because the relative importance of land in the productive equipment of nations varies greatly. The comparative lack of association between land and output is suggested by a comparison of column 10 with columns 4–5 in table 2 and confirmed by E. C. Olson's studies. Let Y represent national income; E, total energy excluding human energy; P, employed population; L head of livestock expressed in livestock units; and A area of cultivated land. If, after the manner of the Douglas-Cobb production function (see note 17 below), $Y = f(P,E,L)$, the following approximate percentage change in Y accompanies a 1 per cent change in the designated variable, given that the other two variables remain unchanged: E, about 0.5 per cent; L, about 0.28; and P, about 0.23. When A is introduced into the income equation, the corresponding percentages become: E, 0.48; L, 0.41; P, 0.35; and A, −0.18. Olson suggests that, since national economies differ in structure and since countries may be grouped into two or three relatively homogeneous categories, the income-estimating equation appropriate for any one of these groups will tend to differ from that most appropriate for the other groups. See Olson, Factors affecting international differences in production, *Amer. Econ. Rev. Proc.* **28** (2): 502–522, 1948. It may strike the reader that Olson's findings run counter to the argument advanced in sections I and II of this paper. This is not the case. The magnitudes of the variables E and L, together with the quality of P and the effectiveness of all three, are functionally related to most of the determinants we have listed and reflect their aggregate influence in a summary manner.

between indices of income and indices of equipment and by the fact that the best-equipped regions (see table 4) are also the regions where income per worker is highest, and conversely. International data centered around 1913 suggest roughly that at that time a \$100 increment in nonlanded capital per worker was accompanied by something like a \$20 increment in his output.[12] Clark estimates the relationship between income ($= y$) and nonlanded capital ($= x$) per worker to be parabolic, with $\log y = 2.884 - 1.108x + 0.323 (\log x)^2$. [13]

Having examined the relations obtaining in particular branches of industry between equipment per worker and output per worker, let us discover if a definite relation obtains between the aggregate income produced within a nation and either all its physical assets or those of its physical assets which are immediately employed to bring this income into being. While our quantitative information relating to this relationship is inadequate for the purposes of our analysis, it may nonetheless be employed to explore the role of capital formation in industrialization.

Let W represent all of a nation's physical assets, and let these be divided into two categories, W_1 and W_2. Within W_1 may be placed all assets which, under prevailing institutional and other relevant conditions, are viewed as yielding income in a significant degree; while within W_2 are included all remaining physical assets, namely, those which, under the given conditions, are yielding no income or significantly little income. Under W_2, therefore, may be included physical assets of the following types: those employed for defense; those utilized for other public purposes (e.g., streets and highways, public schools and buildings and cognate equipment); those in the form of excess reserves (e.g., subsoil wealth and other forms of wealth not in use; excessive inventories at consumer and other levels); consumer durables; and so on. There are also forms of W_1 which, in the early stage of a country's development, closely resemble W_2 and may even be included with it (e.g., railroads).

Let us now call the ratio of income to wealth S, with S equal either to Y/W or to Y/W_1; and let s represent the ratio of the annual increment of income to the annual increment of wealth upon which it is consequent, namely, $\Delta Y/\Delta W$ or $\Delta Y/\Delta W_1$. The value of S, as well as that of s, turns on whether we define it in terms of Y/W or Y/W_1, and, given the latter definition, what assets are included under W_1. In the United States S defined as Y/W had a value of 0.21–0.24 in 1923 and 0.20–0.25 in 1929.[14] The value of S, defined as Y/W_1, has a much higher value, since in a country like the United States W_2 may form 30–45 or more per cent of W. Available estimates suggest that S defined as Y/W_1 has a value lying within or around 0.3–0.35. For example, Fellner, upon defining W_1 to include assets other than monetary metals and land and goods in the hands of consumers, found the ratio s of yearly real output to real capital stock (i.e., $\Delta Y/\Delta W_1$) to range between 0.39 and 0.30 in 1879–1938, with 1919–1938, a period marked by relatively full employment, represented by a value of 0.35.[15] E. H. Stern,[16] having defined W_1 much as Fellner has and having established a regression equation between Y and W_1, discovered the value of s ($= \Delta Y/\Delta W_1$) to approximate 0.3 in both the United States in 1879–1938 and the United Kingdom in 1924–1938. For comparatively underdeveloped South Africa in the 1930's Stern found a corresponding value of around 0.5.

Progress in industrialization and income will be at a maximum only if, the rate of investment being given, the annual increment of investment is appropriately distributed between W_1 and W_2

[12] Estimated from Clark, *Conditions*, 389.

[13] *Economics of 1960*, 74. I have discussed the matters treated in the preceding paragraphs in my Aspects of the Economics of Population Growth, *Southern Econ. Jour.* **14**: 123–147, 233–265, esp. 246–265, 1948.

[14] Physical assets in the United States were evaluated at \$321–353 billion in 1922 and \$428 billion in 1930. National wealth was evaluated at \$309 and \$354 billion, respectively, as of 1923 and 1929, by the National Industrial Conference Board. National income approximated \$87.4 billion in 1929 and \$70–73 billion in 1923. See Doane, R. R., *The anatomy of American wealth*, 35, 37, 120–121, N. Y., Harper, 1940, and U. S. Bureau of the Census, *Historical statistics of the United States, 1789–1945*, 9–11, Washington, D. C., 1949. Of the \$32 billion difference in the 1922 estimates, \$22 billion are attributable to the inclusion of streets, roads, and highways.

[15] Fellner, W., *Monetary policies and full employment*, 78–83, Berkeley, Univ. of Calif. Press, 1946. Of the \$353 billion of national wealth as of the end of 1922 (according to the Federal Trade Commission), only \$183.7 billion is made up of real capital stock, according to Fellner. Kuznets's data on real capita formation are employed to extend the 1922 estimate backwards and forwards.

[16] Stern, E. H., Capital requirements in progressive economies, *Economica* **12**: 163–171, 1945. Stern gives values only for what we have called $1/s$. Comparison of Douglas's figures on capital growth in the United Kingdom with Clark's income estimates suggests that in the period 1875–1909 the value of s was close to 0.3 See Douglas, P. H., *The Theory of wages*, 464, N. Y.. Macmillan, 1934, and Clark, *Conditions . . .*, 397.

and among the various forms of W_1 and W_2 according to their relative significance at the time. For since all forms of W_1 and W_2 absorb some savings, the increase of any one form is always at the expense of others, the volume of savings being given. What constitutes the optimum distribution of savings between W_1 and W_2 turns on a country's stage of industrial development, the degree of complementarity then obtaining between W_1 and W_2, and the degree of sovereignty and choice being allowed consumers. In the earlier stages of industrialization relatively heavy increases of immediately less productive forms of W_1 and of forms of W_2 oriented to collective purposes frequently tend to be indicated. Furthermore, savings sufficient for the forms of investment indicated will not be forthcoming if the rate of saving is too low, or if savings are diverted into nonindicated forms of W_2. While industrial progress tends to be accompanied over the long run by a rise in the ratio of W_2 to W, the rate at which this ratio advances may be curbed through the introduction of appropriate restrictions upon consumer sovereignty and the uses to which savings may be put. Nonetheless, a considerable fraction of the annual savings is bound at all times to be absorbed by W_2 investment. Even so, in view of what has been said, a strong case may be made for appropriate restrictions upon both consumer sovereignty and the disposition of savings in countries undergoing industrial development.

The value of S may fluctuate or undergo nonsecular changes for a number of reasons. (*a*) In view of what has just been said, Y/W will rise if the W_1/W ratio, having deviated from the optimum level, is brought back to it through appropriate investment; it will fall as W_1/W departs from the optimum. (*b*) Y/W will fall if less productive forms of W_2 are increased at the expense of more productive forms even though W_2/W_1 remains constant. (*c*) The value of S falls as the level of employment falls and rises as the level of employment rises. (*d*) The value of S will change, moreover, in response to changes in the number of shifts of workers used per day. For example, if the number of shifts is increased from one to two, W_1 will be used more intensively, with the result that Y/W will rise. Whether an increase in the number of shifts from two to three will further increase Y/W is less certain and must be determined empirically. In general it is advisable that under-developed countries which are short of W_1 operate at least two shifts of workers per day and thereby increase Y/W and improve the prospects for further industrialization. (*e*) The shift of workers from agriculture and forestry into industries in which output per worker is higher tends to hold the value of Y/W at a higher level than would otherwise be sustained. This movement loses force, of course, as the relative number of persons engaged in agriculture and forestry declines.

The value of S is subject to two secular influences which, other conditions being given, cause the value of s to differ from that of S. These influences are population growth and technological and related forms of change. Let us therefore consider the former, under the assumption that technological and related circumstances remain constant. Y progresses in consequence of increases in the labor force (which we shall call L) and its equipment (i.e., W) and as the result of significant changes in other income-affecting forces (e.g., the relative amount of *free* output-affecting agencies; the *quality* of the labor force; the *quality* of equipment; etc.) which we shall call R and for the present suppose to be without effect. If, under these conditions, W increases more rapidly than L, Y will increase less rapidly than W and Y/W will fall, for the value of s ($= \Delta Y/\Delta W$) will be less than that of S ($= Y + \Delta Y/W + \Delta W$) after the change. A similar result is obtained if S and s are defined in terms of Y and W_1.

What has just been said may be illustrated with a numerical example based upon the original Douglas-Cobb[17] production function. Suppose

[17] See Douglas, *op. cit.*, and Are there laws of production? *Amer. Econ. Rev.*, **38**: 1–41, 1948. Let aggregate net output be represented by O; the labor force and its marginal productivity, by L and l; and the marginal productivities of W_1 and W_2 by w_1 and w_2, respectively. Then, in accordance with the usual assumptions,

$$O = Ll + W_1w_1 + W_2w_2.$$

It is usually assumed, moreover, that the ratio of l to w_1 or to w_2, varies inversely with the ratio of L to W_1, or to W_2; if L, W_1, and W_2 each increases by a certain fraction f, O will increase by f since, under the circumstances, l,w_1, and w_2 remain unchanged. Under these conditions the value of $s = \Delta O/(\Delta W_1 + \Delta W_2)$ remains the same as $S = O/(W_1 + W_2)$. If, however, W_1 and W_2 increase by f whereas L remains unchanged in quantity, O will increase by less than f, and the value of s will fall below that of S. This decline would not take place, of course, if some other residual force R were operating either to increase the value of w_1 and w_2 sufficiently, or to contribute enough to the increase of O to offset the decrease in w_1 and w_2. It is because such a force as R is operating through time that the value of s has fallen no more than it has despite the decline in the ratio of L to W, it being assumed that the ratio of W_1 to W_2 remains substantially unchanged. The residual force R is made up of elements not included when O is represented as

we combine 100 units of L with 100 units of W, with each unit of W equal in value terms to 4 units of Y, so that the combination produces 100 units of Y, the marginal product of a unit of L being 3/4 of a unit of Y and the marginal product of a unit of W being 1/4 of a unit of Y. Under the circumstances S has a value of 100/400, or 0.25, and the average output per unit of L is 1 unit of Y. These values will remain unchanged if we increase L and W by one per cent each. But suppose we hold L constant at 100, and increase W to 101, it being assumed that 4 per cent of the preceding year's income of 100 units of Y has been saved and invested in W. The aggregate income will now approximate 100.25 units of income; the average output per unit of L will be 1.0025; the value of s will be, in terms of Y, approximately 0.25/4, or .0625; and the value of S will have fallen, in terms of Y, from 0.25 to 100.25/404. Since, if L had also increased 1 per cent, the average output of L would have continued at the level of 1 instead of rising to 1.0025, we may say that a 1 per cent increase in L (i.e., population) costs the population a 1/4 of one per cent increase in per capita income. If the respective marginal productivities of W and L were not 1/4 and 3/4, respectively, but 1/2 each, the value of s would be 0.5/4, or 0.125, and the cost of a 1 per cent increase in L would be the prevention of a 1/2 of one per cent increase in per capita income. Under static conditions, therefore, an increase in W unaccompanied by a corresponding increase in L, operates to reduce s and S. In consequence the income-opportunity cost of population growth is *relatively* lower than when conditions are dynamic and S manifests a lesser tendency to fall.

Let us now hold L relatively constant and suppose that dynamic changes represented by changes in the value of R accompany the increase in W. Changes of this sort presuppose an increase in W since most of them must find embodiment in material equipment before they can become effective. In consequence of changes of this sort, therefore, the combined marginal productivities of L and W may rise sufficiently to cause Y to increase nearly as rapidly as W and conceivably more rapidly, for the production function itself is modified. Dynamic changes of the sort we have lumped together under the residual R thus operate, if they are favorable on the balance, to cushion the tendency of S to fall as the ratio W/L rises. Changes of this sort thus increase the opportunity cost, in terms of per capita income, of population growth. Thus if, even though L is constant, dynamic change prevents a decline in S, a 1 per cent increase in population will cost a 1 per cent increase in per capita income whereas, if S falls in value, this cost, as we have seen, will be somewhat lower. Under all circumstances, however, so long as a nation's population is in excess of the optimum in size, an increase in population must entail some cost in terms of per capita income.

Both population growth and technological and similar improvements have operated in industrialized countries to prevent greater declines in S and s than otherwise would have been experienced. In the United States, for example, although W_1 increased more than twice as fast as L between the 1880's and the 1920's, the value of s defined as $\Delta Y/\Delta W_1$ declined only about one-tenth.[18] Had L not grown at all, the value of s thus defined would have fallen about one-half. The decline in the value of s (similarly defined) in the United Kingdom since the 1860's appears to

a function only of L, W_1, and W_2. Representative of these elements are changes in the quality of L, W_1, and W_2, changes in the influence of "free" resources, changes in organization, invention, innovation, and so on.

Let us, in keeping with what has been said, change the form of our production function from $O = f(L, W_1, W_2)$ to $O = f(L, W_1, W_2, R)$, with R subject to variation whether or no all the other variables vary. Accordingly, even though W_1 and W_2 increase by f while L increases by less than f, O still will increase by f if R varies enough in an output-increasing direction to offset the failure of L to increase by f. It is because production functions are not usually defined to include a variable such as R and take its influence into account that economists find difficulty in accounting for the fact that O sometimes increases by more or less than f in the world of reality even when L, W_1, and W_2 each increases by f, or in explaining the fact that O may sometimes increase by f even when, with W_1 and W_2 (say) increasing by f, L increases by less than f. The accounts of Stigler and Allen indicate that the role of a residual force similar to R is not customarily made use of to cope with the problem of "increasing" and "decreasing" returns. See Stigler, G. J., *Production and distribution theories*, chap. 12, N. Y., Macmillan, 1941; Allen, R. G. D., *Mathematical analysis for economists*, 264–265, 317–319, London, Macmillan, 1938; also note 11 above.

[18] In the United States, between a period centered around 1883 and one centered around 1928, the following increases per year took place: aggregate real output, 3.5 per cent; real capital stock, just under 4; the labor force, about 1.75; and real output per capita, about 2. The rates are based upon Fellner's estimates. See *op. cit.*, 80. Carl Snyder estimated that, between 1850 and 1930, the ratio of capital to annual value of product nearly doubled. See *Capitalism the creator*, 126, N. Y., Macmillan, 1940. On the ratio of wealth to income see also Cassel, G., *On quantitative thinking in economics*, chap. 6, Oxford, Clarendon Press. 1935.

have been greater, perhaps around one-fifth[19]; but it would have been greater still had L not grown. In both countries continuing improvements in technology called for and absorbed savings, elevated the marginal productivity of labor, at least weakened the tendency for the marginal productivity of capital to fall, and thus operated, together with increases in L, to prevent much greater declines in S than would otherwise have been experienced. In the future in under-developed countries both technological and demographic change will serve to sustain the value of S; in industrialized countries technological change will be the principal source of support for S.

Analysis of the part played by savings and capital formation in industrialization entails two choices. First, one must define S either as Y/W or as Y/W_1. In view of the fact that the industrialization of under-developed countries involves heavy and continuing outlays for many forms of capital included under W_2, the Y/W definition appears to be the more useful. Second, we must determine upon a value for Y/W representative of under-developed countries. In the United States Y/W has a value in the neighborhood of one-fifth. This value must be much higher in non-industrialized countries where capital is scarce and S has not yet fallen in consequence of progress in industrialization. A value of 0.4 or higher is probably indicated. For example, since the value of Y/W_1 (as noted earlier) has been about 1.67 times as high in South Africa as in the United States, and since the ratio W_1/W must be somewhat higher in South Africa than in the United States, it is likely that Y/W has a value in the neighborhood of 0.4 in South Africa. Comparison of annual savings and investment rates with the rate of growth of income suggests that in Japan in 1908–1925 S, or $\Delta Y/W$, probably had a value close to 0.4.[20] In less developed countries than South Africa and Japan the value of both Y/W and $\Delta Y/\Delta W$ probably exceeds 0.4. For purposes of analysis we shall assume that in under-developed countries S $(= Y/W)$ has a value in the neighborhood of 0.4 and that the combined influence of population growth and technological progress will keep the value of both S and s $(=\Delta Y/\Delta W)$ in this neighborhood. If our estimate is too low, we shall underestimate the influence of industrialization whereas, if it is too high, we shall overestimate it.

In the absence of an aggressive, state-supported, and state-implemented program for birth control and planned parenthood in the non-industrialized countries, it is likely that their populations will increase 1–1.5 per cent per year. For these populations are coiled or Oriental in character, being marked by high mortality, low life expectancy, high natality, and high potential rates of increase which will tend to be actualized under the impact of such improvements in economic conditions as accompany industrialization. As we have already indicated, an increase of 1 per cent in population may cost an 0.5–1 per cent increase in per capita income. It is advisable, therefore, that programs for industrialization also include plans for the diffusion of cheap and practical means of contraception and the stimulation of their use.

(*b*) Let us turn now to estimating the capital and savings requirements of under-developed countries, in especial those with per capita incomes in the neighborhood of $100 and with 60 or more per cent of the labor force engaged in agriculture and forestry. We shall first have recourse to a hypothetical, though representative, case. Subsequently we shall formulate the problem in more general terms.

Suppose a country with a population of 1,000,000; a labor force of 350,000, 80 per cent of whom are engaged in agriculture and forestry; per capita and aggregate equipment (i.e., W) of $250 and $250 million, respectively, with equipment per worker averaging $714 and other wealth averaging $50 per capita.[21] Suppose that S defined

[19] This statement is based upon data presented by Stern, Douglas, and Clark, whose works are cited in notes 16–17 above.

[20] According to Clark (see *Conditions* . . . , 116 ff., 406) between 1897 and 1928 the national income of Japan advanced about 4.75 per cent per year while savings approximated one-fifth of the national income, suggesting that $\Delta Y/\Delta W$ had a value of only about 0.24. However, Staley's figures on the progress of the national income between 1900–1909 and 1920–1929 and the annual rate of investment suggest that $\Delta Y/\Delta W$ probably had a value in excess of 0.4. This estimate appears to be too high in consequence of exaggeration of the rate of income growth. Between 1908 and 1925, according to Clark's estimates, national income advanced nearly 5.5 per cent per year, while investment, according to Staley's figures when made comparable with Clark's, absorbed about 14 per cent of the national income. Accordingly, $\Delta Y/\Delta W$ must have been around 0.4. See Staley, E., *World economic development*, appendix to chap. 4, Montreal, International Labor Office, 1944. According to estimates reported by H. G. Moulton for 1928 Japan's national income approximated only 10.7 per cent of her estimated wealth. This ratio is obviously much too low. See Moulton, *Japan*, 248, 614, Washington, Brookings Instn., 1931.

[21] Our assumption that one-fifth of the hypothetical country's wealth is devoted to purposes other than equipping

as Y/W remains constant at its initial value of 0.4. Suppose further that we plan, over a 25-year period, to transfer 140,000 workers out of agriculture, and reduce the agricultural fraction of the labor force to 31 per cent, given a 1 per cent annual increase in population, and to 24 per cent, given a 2 per cent annual increase. Suppose, finally, that we equip all new and transferring workers at $1,500 per head; that over the 25-year period we gradually raise equipment per worker of all other workers from $714 to $1,500; and that we increase non-business equipment per inhabitant 1 per cent per year.

The plan outlined will absorb about 13.8 per cent per year of the national income for 25 years if the population continues to increase 1 per cent per year, and about 19.5 per cent if the population grows 2 per cent per year.[22] Since S is assumed to remain constant at 0.4 and since about 8 per cent of the annual income is devoted to increasing equipment per worker and per capita, per capita income will increase about 3.2 per cent per year, rising, in the course of the 25 year period, from the initial $100 to nearly $220. It is quite unlikely that, short of considerable foreign investment, the 13.8 per cent investment rate, required when population grows 1 per cent per year, can be realized. The 19.5 cent investment rate, required if population grows 2 per cent per year, seems impossible of attainment short of very considerable foreign assistance.

Proponents of industrialization usually emphasize the increase in aggregate and per capita income to be obtained from a shift of the excess labor force out of agriculture, in which there usually is much disguised unemployment, and into appropriate non-agricultural occupations. Suppose 80 per cent of the labor force is engaged in agriculture where output per worker is 1 in contrast with 2–3 in non-agricultural occupations. Then the transfer of 1/80 of the agricultural labor to non-agricultural employments will, under essentially static conditions and on condition that agricultural output remains unchanged,[23] permit an increase of between 1/60 and 3/140 in total output. Given the dynamic conditions which accompany industrialization, however, the increase may be greater. It has been estimated, for example, that a 1 per cent decrease in the number of persons engaged in primary occupations tends to be accompanied by a 3.94 per cent increase in per capita income.[23] In our discussion we do not take this transfer problem explicitly into account, since it is automatically taken care of when the capital stock is increased and employed where it is most effective, and since its direct influence virtually ends in most countries when the relative number of persons engaged in agriculture falls significantly below one-fifth. The comparative lowness of output in agriculture appears to be attributable to the relatively small amount and poor quality of the equipment employed therein, to the lesser education of agricultural workers, to the presence of much disguised unemployment, and, when agriculturalists are exploited, to the unfavorable terms of trade. Accordingly, given an adequate supply of capital and an appropriate redistribution of workers among occupations, the differences between agricultural and nonagricultural productivity per worker tend to be eliminated.

We may now formulate in more general terms the relation obtaining between capital formation and progress in industrialization and income. We have already defined Y, W, W_1, and W_2. For present purposes we shall define S as Y/W and s as $\Delta Y/\Delta W$. Let p represent population and r

the labor force is suppositional and may be too low. In the United States in the last half of the nineteenth century, dwellings, household equipment, clothing, personal ornaments, theatres, churches, etc. comprised 20–25 per cent of the estimated tangible wealth. See Doane, *op. cit.*, 263.

[22] Equipment of the transferring and the non-transferring workers will cost about $7.5 million, or 7.5 per cent of the national income in the first year, and a like percentage in subsequent years as the absolute outlay is stepped up with the rise in income. Equipping a 1 per cent increase in the labor force will cost $5.25 million, or 5.25 per cent of the national income, in the first year, and double this amount if the labor force increases 2 per cent per year. The absolute outlay will rise in later years, but the percentage figure will remain around the first-year level. Non-business capital formation will absorb 1 and 1.5 per cent per year of the national income, given population growth rates of 1 and 2 per cent, respectively.

[23] Suppose 80 per cent of the labor force is engaged in agriculture where output per worker is 1 and that average (= marginal) output per worker in non-agricultural employments is 3. Then a transfer of 1/80 of the agricultural labor force to non-agricultural occupations will increase aggregate income 2–3/140, or 1.4–2.14 per cent. Under dynamic conditions the effect may be larger. Thus S. Raushenbush estimates that a 1 per cent decrease in the relative number in primary occupations tends to be accompanied by a 3.94 per cent increase in per capita income. See *People, food, machines*, 79, Washington, Public Affairs Inst., 1950. See also L. Bean's estimates in *Studies in income and wealth*, Part Five, N. Y., National Bureau of Economic Research, 1946; and Ezekial, M., *Towards world prosperity*, 14–29, N. Y., Harper, 1947. See column 11 in table 2 and line 8 in table 1 on the relative number engaged in agriculture by country.

its annual rate of increase in per cent; y, per capita income and j its annual rate of increase in per cent; and i, the annual rate of increase in Y in per cent. Let a represent the annual increment in W expressed as a percentage of Y. Furthermore, let a be broken up into its two components, each expressed as a percentage of Y, with a_1 representing the increment in W originating in domestic saving and a_2 the increment originating in net investment flowing in from abroad. We may now express the annual rate of increase in Y as

$$i = s(a_1 + a_2).$$

If the value of S is constant and equal to that of s, we may substitute S for s. However, since s tends to differ from S and to decline as W/p increases, a corrective factor c, with a value less than unity, must be employed to reduce the value of S appropriately so that

$$i = S(a_1 + a_2)c.$$

Then the annual rate of increase in y may be expressed as

$$j = \frac{1 + S(a_1 + a_2)c}{1 + r} - 1.$$

This last equation indicates that so long as s remains constant or as c has a value of unity, a 1 per cent increase in population costs approximately a 1 per cent increase in per capita income; but that, if c has a value less than unity, the cost in terms of j is less than 1 per cent.[24]

Let us now assign values to the elements composing the equation for j. We have already assigned a value of 0.4 to S and we shall assume it to remain constant for 50 years. To r we may assign a value of 1 per cent. For reasons to be indicated we may assign to a_1 a value of 0.03–0.12 Y, and to a_2 a value not in excess of $0.33a_1$. Accordingly, a tends to have a value ranging between 0.04 and 0.16 Y. These values suggest that i will assume a value ranging between 0.016 and 0.064 Y, while j will assume a value lying between 0.006 and 0.053 Y. Judging by past experience the value of j is not likely long to exceed 4 per cent per year unless the countries undergoing industrialization experience much more foreign assistance than did Japan, the non-Western under-developed country whose industrial progress has been the most remarkable.

Let us now examine the values we have assigned to a_1 and a_2. In the nineteenth and early twentieth centuries the average annual propensity to save (let us call it q) ranged between 0 and 20 per cent.[25] But not all of q is likely to assume the form of W, there being a fractional wastage w of q, such that $a_1 = (1-w)q$. If w normally has a value lying between 0.1 and 0.2, we may suppose that a_1 will approximate $0.8–0.9q$. If this is the case, a_1 may conceivably attain a value as high as 0.16 Y provided that conditions extremely favorable to saving are maintained and that the value of w is held down. In practice, however, it is doubtful, given the lowness of per capita income in the under-developed countries, whether q will be high enough and w low enough to permit a_1 to assume a value in excess of 0.12 Y, if that much. For reasons that we develop later, it does not appear feasible long to elevate a_2 above 0.33 a_1, since when a value of this order is exceeded foreign investment is not likely to be effectively absorbed and/or serviced. As a rule, over long

[24] The statement of the income:capital problem in this paragraph resembles that developed by Domar in his attempt to estimate the amount of income growth needed to absorb the amount of savings provided when income is at the full employment level. His emphasis is upon the maintenance of full employment whereas ours is upon the supply of enough savings (= investment) to sustain a high rate of income growth. Furthermore, his definition of s approximates our $\Delta Y/\Delta W_1$. On the income:capital relationship see Harrod, R. F., *Towards a dynamic economics*, chap. 3, London, Macmillan, 1948; Domar, E. D., Capital expansion, rate of growth, and employment, *Economica*, **14**: 137–147, 1946, Expansion and employment, *Amer. Econ. Rev.*, **37**: 34–55, 1947, and The problem of capital accumulation, *ibid.*, **38**: 777–794, 1948; Schelling, T. C., Capital growth and equilibrium, *ibid.* **37**, 864–876, 1947; Stern, E. H., The problem of capital accumulation, *ibid.* **39**: 1160–1169, 1949; and Robinson, Joan, Mr. Harrod's dynamics, *Econ. Jour.* **59**: 68–85, 1949.

[25] In the late nineteenth and the early twentieth centuries the ratio of savings to national income normally ranged between 5 and 20 per cent, with an intermediate range of 8–14 representative of most countries. Per capita income has rarely grown more than 2 per cent per year over a period of 40–50 years, Japan affording the only instance in which it long progressed at a rate close to 4 per cent. See Clark, *Conditions*, 148, 406, and *Economics of 1960*, chap. 6; Domar, E. D., The "burden of the debt" and the National Income, *Amer. Econ. Rev.* **36**: 826, 1944; Goldenberg, L., Saving in a state with a stationary population, *Quart. Jour. Econ.* **59**: 50, 65, 1946. In the countries of Western Europe in 1938, gross domestic investment expressed as a percentage of gross national product, ranged between 6 in Czechoslovakia and 25 in Sweden, in contrast with 8 in the United States. Net foreign investment ranged from plus 2 to minus 2 per cent of gross national product. In 1947 both gross domestic and net foreign investment were appreciably higher, see United Nations, *Selected world economic indices*, 50, Lake Success, United Nations, 1948.

periods the value of a_2 lies below one-third of a_1. It should be noted that, because of waste of foreign exchange, the absolute amount of foreign investment in a country tends to fall short of the amount of exchange that appears to be available for such use.

Growth of per capita income in under-developed countries at a rate of 3–4 per cent per year—i.e., at a rate double that in prospect in industrialized countries—presupposes that at least two conditions will be met by non-industrialized countries. First, these countries must step up q, minimize w, compel most savings to assume the form either of W_1 or of the comparatively essential types of W_2, attract foreign capital, and utilize virtually all of their foreign exchange for the servicing of foreign debt and the procurement of relatively productive kinds of equipment and services not obtainable at home. Among the complementary courses of action suited to accomplish this first condition are the following: (*a*) establishment of foreign exchange controls which are designed to divert foreign exchange to uses that directly or indirectly increase output; (*b*) creation of financial and related institutions which will assemble the savings of large and small income-receivers and shunt them into appropriate lines of activity; (*c*) employment of the apparatus of state to compel most of the income received by wealthy though unenterprising individuals to assume the form of W_1 and of essential types of W_2.

Second, it is essential that S and s not decline appreciably in value. Attainment of this objective turns on there being available either a sufficient supply of arable land and other essential natural resources, or means by which shortages of these factors can be made up. While there will probably be enough land in most of Latin America and Africa, there will be far too little in Asia and the Caribbean area (see table 2, column 10, and table 4, lines 4–7).[26] It is essential, therefore, that steps be taken to alleviate the shortage of arable land in these land-lacking regions (e.g.: increased investment per acre; control of plant and animal diseases; substitution of more productive for less productive plant and animal types; and development of a diet which, though predominantly vegetable in character as at present [see columns 7–9 in table 3 and lines 23–26 in table 1] is adequate).

Data presented in column 9 of table 2 and line 11 of table 4 indicate that energy resources (other than atomic)[27] are probably in too short supply to permit great industrial development in much of Latin America, in much of the Near East and Southern Asia, and in many parts of Africa, particularly since this shortage of energy reserves is accentuated in many of the energy-lacking regions by an associated shortage of iron ore and other crucial minerals.[28] It appears, therefore,

[26] Data relating to crop land per capita (see table 2, column 10, and table 4, line 4) indicate that the amount of crop land in use per inhabitant is hazardously low in regions other than the Western Hemisphere, Oceania, and Russia. Data relating to the amount of land which, though now in forest, is both accessible and susceptible of being used for agriculture (see table 4, line 7) indicate the per capita amounts to be smallest in the regions where the shortage of arable land is already most pronounced. The importance of this point is accentuated by the fact that several acres of forest land are required per capita to supply minimal timber and related requirements. It may be said, in general, that there exists in the world a sufficiency of arable land, if it be brought into use and used effectively, to supply the food requirements of an expanding world population. The practical significance of this potential supply of arable land is greatly reduced, however, by the fact that its location and ownership, together with institutional and economic obstacles in the way of its use, make this land relatively inaccessible to the land-short peoples. (In geological time, of course, the rise in world temperature initially will add to the supply of cultivatable land. This trend is not relevant to the present argument, however, since the rate of change per time period is so much greater for population than for the supply of cultivatable land.) On the above issues see Brown, A. J., *Industrialization and trade*, 18–25, London, Oxford Press, 1943, and my The World's Hunger—Malthus, 1948, *Annals Acad. Polit. Sci. Columbia Univ.*, 53–71, 1949. It appears, therefore, that efforts to increase yields per acre offer a more practical solution to the food problem in the land-short countries of the world than do efforts to augment the area under cultivation. For it has been estimated that plant and animal yields may be increased as much as 50 per cent or more in a few years through the introduction of better methods of cultivation, improved plant and animal varieties and breeds, modern animal breeding and feeding methods, and effective disease, pest, and fungi controls. See United Nations, *Technical assistance for economic development*, 22–24, 138, 143–145, 152–156, 182, Lake Success, United Nations, 1949.

[27] Commercially exploitable deposits of uranium ore reportedly are to be found principally in the Belgian Congo, Canada, Czechoslovakia, and the United States.

[28] Data on energy resources are given in Guyol, *op. cit.*; Brown, *op. cit.*, 18–24; and Usher, A. P., The resource requirements of an industrial economy, *Jour. Econ. Hist.* **7**; Supp. **7**: 35–46, 1947. Brown reports iron ore supplies in terms of millions of tons of metal content as follows: Western Europe, 8,485; Eastern Europe, 472; United States, Canada, Cuba, and Newfoundland, 9,000; Australia and New Zealand, 200; South Africa, 3,000; Argentina, Uruguay, and Chile, 250; U.S.S.R., 16,000; India, 2,330; China, 650; Japan, 30. Considerable iron ore is to be found also in Brazil, Rhodesia, and Egypt. See table 4, line 12, on supplies by continent. Venezuela's newly discovered deposits are extraordinarily rich.

that even though these shortages may be somewhat counterbalanced by economy in resource use and by the tendency of returns to increase with industrialization,[29] they probably cannot be wholly compensated. It follows, if this be the case, that S and s will be under strong pressure to fall, and that advancing per capita income 3–4 per cent per year for many years will not be easy even if it should prove possible.

IV. INDUSTRIAL COMPOSITION AND INDUSTRIAL DEVELOPMENT

Maximization of the rate of industrialization, other conditions being given, requires that both investment and the labor force be appropriately distributed among the industries that compose or may compose a developing economy. Such distribution presupposes both recognition of each of the following sometimes antithetical principles and the assignment of appropriate weight to each. These principles are: (1) full account must be taken of the implications of the fact that much capital equipment is immobile, and that a considerable fraction of this immobile equipment is not very productive directly and/or immediately; (2) due weight must be given to the establishment of industries which ease the pressure for foreign exchange; (3) it is essential that, in so far as possible, industries suited to satisfy the more urgent consumer wants be given the highest priority; (4) capital should initially be directed, in so far as possible, into industries (i) characterized by low capital-intensity and (ii) capable of utilizing most effectively the kinds of labor available and/or in relatively immediate prospective supply; (5) industrial development should proceed along lines suited to exploit the relatively more accessible land and natural-resource equipment of a country; (6) a workable balance must be maintained among the industries composing an economy so that, given prospective foreign trade relations and the fact that some industries must initially be developed ahead of the market, inter-industry complementarities may be taken advantage of and uneconomic and excess capacity may be averted.

(1) Inasmuch as a major fraction of the physical assets used for productive purposes—two-thirds or more when land, roads, and highways are included in the total and one-half or more when they are excluded [30]—is immobile, account must be taken of the restrictions imposed by this immobility. (*a*) A country must produce more than half of its capital equipment and probably cannot with safety long attempt to secure more than one-fourth of its annual increment through foreign borrowing. (*b*) While, other conditions being equal, the ratio of some forms of immobile equipment (e.g., highways, railroads, communications, etc.) to the population tends to be higher in sparsely than in densely peopled countries,[31] any advantage derivable therefrom by the latter countries tends to be more than offset by the associated low ratio of cultivatable land to the population. (*c*) Since underdeveloped economies tend to be ridden with various kinds of unemployment, these countries may easily utilize their unemployed and ineffectively employed workers to build immobile capital (buildings, highways, railroads, communications, etc.) and thus obtain it at relatively small net cost to the economy. (*d*) When a country embarks upon an industrialization program, it tends initially to encounter a sub-normal value of s, since the ratio of immobile to mobile equipment is abnormally high at first, and the immobile capital, being *directly* less productive on the average than are other forms of investment, contributes in a relatively smaller measure to the embarking country's income. As industrialization proceeds, however, mobile and more productive equipment tends (at least within limits and for a time) to increase relatively more rapidly than assets that are immobile and directly less productive. This trend tends to push up the values of s and S to the high levels seemingly

[29] See Jones, G. T., *Increasing return*, Cambridge, Cambridge Univ. Press, 1933; Clark, *Conditions*, 306–317, and The productivity of manufacturing industry, *Rev. Econ. Progress* 1 (8–10), 1949.

[30] According to Doane's estimates about 70 per cent of the physical assets used for production in 1922 and about 65 per cent of all physical assets were essentially immobile. If investment in roads and highways is included these percentages become 75 and 70. If investment in land, roads, and highways is excluded the percentages are 52 and 47. These estimates are rough approximations. See Doane, *op. cit.*, 35, 37, 116, 120–121. See also Buchanan, N. S., *International investment and domestic welfare*, chaps. 2, 6–7, N. Y., Holt, 1945; Buchanan, N. S. and Lutz, F. A., *Foreign economic relations of the United States*, chap. 8, N. Y., Twentieth Century Fund, 1946. It has recently been estimated that of the agricultural investment feasible in underdeveloped countries in the next decade, about 71 per cent is composed of equipment and services that will have to be imported. See United Nations, *Methods of financing economic development in under-developed countries*, 55–56, Lake Success, United Nations, 1949.

[31] In Japan the ratio of population-oriented to space-oriented investment rose from 1.67/1 in 1900–09 to 3.4–4.1/1 in 1919–36. See Staley, *op. cit.*, chap. 4, appendix.

normal for under-developed countries.[32] Illustrative of immobile and immediately less productive investments indicated for under-developed countries are canals, railroads, highways, land-clearing, buildings for needed industries and essential public activities, and irrigation, drainage, and flood-control projects suited to improve agriculture, provide hydroelectric power, and facilitate the control of disease (e.g., malaria).[33]

(2) Because of the composition of an economy's physical assets (noted under [1]) and because of the difficulties that an industrializing country encounters in its efforts to secure an adequate supply of foreign exchange, it is advisable, other things being equal, that investment be canalized into industries which can ease this pressure of the demand for foreign exchange against its necessarily limited supply. These industries are of two sorts: (*a*) those producing goods that were previously imported; and (*b*) those producing goods for export. Class (*a*) industries comprise principally firms that produce cheap and relatively labor-embodying manufactures (e.g., food products, textiles, simple house furnishings, etc.) while class (*b*) industries comprise firms that produce raw materials and partly manufactured products.[34] In the past foreign investment in under-developed countries has tended to flow into transportation, water-power, power, and other utility developments, into mineral raw-material producing industries, and into branches of agriculture that supply food-stuffs and agricultural raw materials required in advanced countries.[35]

(3) In view of the lowness of the scale of living prevailing in most non-industrialized countries, and in light of the manner in which the composition of economic output has evolved in the past, it is essential that primary emphasis long be placed upon increasing the supply of consumer

[32] Data suited to demonstrate the points made above in the text are not readily available. Some circumstances tend to increase the productive effectiveness of W while others tend to diminish it. Industrialization initially entails two types of investment on the part of under-developed countries which, since they are not directly productive, must be financed from government funds: (*a*) the execution of "projects which are essential to organic development" and (*b*) the provision of expanded social services. (See United Nations, *The effects of taxation on foreign trade and investment*, 4, Lake Success, United Nations, 1950.) Since these investments cannot be nicely adjusted to the size, income, and needs of the population, they sometimes tend to be too large initially, with the result that their effectiveness increases with time. Data presented in table 1, line 13, and table 3, column 2b, reveal that only after economies have progressed appreciably are railroad facilities adequately used and indicate that initially subsidies out of tax revenues tend to be required. If data were available they would permit similar inferences in respect of highways and related facilities. Doane's data (*op. cit.*, chap. 7 and appendix D) suggest that after industrialization had made some progress in the United States, directly productive mobile assets tended to increase faster than mobile assets. In short, for reasons such as have been illustrated, the effectiveness of W probably tends to increase because W_2 or closely related forms of wealth come to be more fully used. In time, however, as income rises, the ratio of W_2 to W_1 tends to rise, with the result that Y/W falls. Data on the ratio of capital (exclusive of farm land and natural wealth) to income, by industry, in the United States in 1929, suggest that Y/W may vary in response to the composition of the industrial component of W, for these ratios vary: agriculture, 3.1; mining, 3.3; transport and communications, 4.8; electric light, power, and gas, 12.2; all manufacturing 3.5; trade, banking and insurance, 2.6; all the groups covered, 3.9. (These intergroup differences are attributable in much larger measure to differences in the capital-labor ratio than to differences in the productivity of capital as such.) See Hilgerdt, F., *Industrialization and Foreign Trade*, 47–48, Geneva, League of Nations, 1945.

[33] See United Nations, *Methods of financing economic development in under-developed countries*, 44–50, Lake Success, United Nations, 1949; FAO, *Mission for Greece*, 160–162, Washington, FAO, 1947.

[34] See Buchanan, *op. cit.*, 102–106. In the 1920's and 1930's the non-industrialized countries imported manufactured articles and exported raw materials predominantly. See League of Nations, *The network of world trade*, 23–24, Geneva, League of Nations, 1942.

[35] While agriculture, as a whole, has not attracted foreign capital, forms of agriculture adapted to foreign control have; e.g., bananas, sugar, vegetable oils, rubber, tea, coffee, spices, cinchona bark, sisal, abacá, chicle, cacao, kapok, tobacco, cotton, timber, and grazing and related industries. A number of mineral resources have attracted foreign capital: e.g., petroleum, iron ore and ferro-alloys, non-ferrous metals, fertilizer raw materials and other non-metals. Coal production has not drawn foreign capital. Some foreign capital has flowed into water-power developments in under-developed countries and more may do so. Transportation, telecommunications, and other public utilities have drawn foreign capital into under-developed countries. There has been very little foreign investment in manufacturing in under-developed areas. See Lewis, C., *The United States and foreign investment problems*, chap. 5, Washington, Brookings Instn., 1948. Of the $11.4 billion private American direct investments abroad in 1948 4.2 were in petroleum, mining, and smelting; 1.3 in public utilities; 3.6 in manufacturing; and 0.6 in agriculture. See Abelson, M., Private United States direct investments abroad, *Survey of Current Business*, 29: 20, 1949. The nature of these investments supports the conclusion of one study "that foreign capital is in the main confined to preparing the way for . . . industrialization [in the form of manufacturing for the home market], and that, when it has done so, the growth of manufacturing for the domestic market will in the main have to rely on domestic capital formation." See United Nations, *International capital movements during the inter-war period*, 33–34, Lake Success, United Nations, 1949.

goods and services in most of the countries here under consideration.

This inference is supported by revelations concerning the dietary and health deficiencies found in these countries and by the principles of consumptive evolution implicit in family budgets when classified according to level of disposable family income. On the assumption that individual and corporate savings constitute an effective demand for capital goods, analyses of budgets in a given country, classified according to income, may serve to disclose roughly how the composition of private expenditure will evolve as industrialization progresses and familial income rises. If we combine with this projection one of public expenditure based upon the past response of the composition of governmental outlay to increases in per capita income and another of the prospective composition of exports and imports, we have a composite projection of the composition of prospective economic output and an indication how capital and man-power should be disposed in the future. Analysis along these lines indicates that for years to come the non-industrialized countries must concentrate upon increasing their output of consumer goods.[36] Typical of the consumer industries initially indicated for under-developed countries are those suited to preserve, process, and distribute food; to produce cheaper textiles and simple types of farm equipment; and to manufacture inexpensive home furnishings and equipment. Typical of the more durable industries indicated are housing, building, and simple health-improving ventures.

Historical analysis bears out this inference, for it reveals that industrialization is attended by complementary changes in the composition of employment and output. (*a*) The absolute and the relative number of persons engaged in agriculture, forestry, and fishing tends to decline until, assuming that a country in effect just supplies its requirement of the products of these industries, the relative number engaged therein reaches a level of 8–20 per cent of the labor force. The relative number engaged in manufacturing, mining, and building begins to rise only to be surpassed, after some decades, by the relative number engaged in the supply of ever more diverse services. (*b*) Within the industrial sector proper, as a rule, consumption-goods industries remain paramount for many decades, but in a decreasing measure. The rapidity with which the capital-goods industries overtake consumption-goods industries in relative importance is greater in proportion as (i) the necessary raw materials are available at home or readily obtainable abroad and as (ii) the state restricts consumer sovereignty and choice and takes steps forcibly to accelerate the development of capital-goods industries. For example, the capital-goods industries progressed more rapidly in the resource-rich United States and in totalitarian Russia than in Western Europe where the resource equipment was poorer than in the United States and the consumers were much freer than in Soviet Russia. Capital-goods industries have tended to develop more rapidly, furthermore, in countries which, because they undertook industrialization more recently, were able to profit by the experiences of countries that underwent this process earlier. Industrial history thus reveals, in considerable measure, the operation of a principle analogous to the biological principle embodied in the dictum that ontogeny recapitulates phylogeny; for the development of any particular country lately undergoing industrialization recapitulates in a significant degree the course of events experienced by countries that have preceded it in industrialization.[37]

(4) Inasmuch as non-industrialized countries are relatively short of both capital and skilled labor they must, in so far as possible, economize in the use of each of these agents. This means that they must emphasize industries in which the ratio of capital to labor is low and/or in which the ratio of skilled to relatively unskilled workers is low. Accordingly, if as theory leads us to expect, both capital and diverse kinds of labor are distributed among employments so that each such

[36] On family-budget behavior see Zimmerman, C. C., *Consumption and standards of living*, N. Y., Van Nostrand, 1936; Allen, R. G. D., and Bowley, A. L., *Family expenditure*, London, P. S. King, 1935; Williams, F. M., and Zimmerman, C. C., *Studies of family living in the United States and other countries*, Washington, U. S. Dept. of Agriculture, 1935. For an estimate of structure of evolving wants from budgetary studies see *The structure of the American economy*, chap. 2, Washington, Nat. Resources Comm., 1939.

[37] On these points see Clark, *Conditions*, chaps. 5–6, and *Economics of 1906*, chap. 5; Chang, *op. cit.*, chap. 3; Hoffmann, W., *Stadien und Typen der Industrialisierung: Eine Beitrag zur quantitativen Analyse historischer Wirtschaftsprozesse*, Jena, Fischer, 1931, and The growth of industrial production in Great Britain: A quantitative study: *Econ. Hist. Rev.* 2: 162–180, 1949. Great Britain, which began to industrialize much earlier than did Japan, and which allowed its population far more consumer sovereignty and choice than did Soviet Russia, passed from the first through the second and into the third stage of industrialization much less rapidly than did Japan or Russia, the studies of Hoffmann and Chang show.

agent receives essentially the same remuneration in all employments, the ratio of wages to average output will be lower in the capital-intensive than in the labor-intensive industries while the wage structure will be essentially the same from industry to industry. Actually, this situation tends only to be approximated. Even so, in the absence of strong governmental intervention, the pressure of internal and/or external competition will cause the under-developed countries initially to specialize in industries that make relatively little use of capital and skilled labor. These countries cannot, of course, develop only industries of this sort, for embarkation upon an industrialization program calls for considerable investment in capital-intensive branches of the economy[38] and for the employment of an adequate number of skilled workers and technically competent people. In general, industrial development can proceed successfully only if it progresses upward from the bottom, and no steps are taken in the absence of the necessary preliminary preparation.[39]

(i) While the amount of investment required per job usually may be varied somewhat, given the production functions technologically practicable, and while production functions for given industries vary from country to country, it remains true that capital investment per job varies widely from industry to industry and, in a lesser degree, from one branch of a given industry to another. What is more important, such variation characterizes both investment in land and buildings (which must be produced at home) and investment in plant and machinery (much of which has to be imported in the case of countries that have made little progress in industrialization). Investment per job is comparatively low in terms of both domestically-produced and foreign-produced capital in furniture and house furnishings, clothing, textile, leather and related industries. It is relatively small also in light metals, electrical products, semimanufactured metals, engineering, and some building materials. While it is relatively large in food, drink, and tobacco products as a whole, it is relatively small also in some branches of industry. In short, investment per worker is relatively low in most of the industries that rate high priority under (3), only the importation of equipment, steel, motors, and the like being necessary in the early and intermediate stages of industrialization. While investment per job is necessarily very high in electric light and power and other utilities and likely to be high in industries oriented to raw materials, foreign capital is likely to be obtainable for these purposes, and particularly for the development of raw materials marketable abroad.[40]

(ii) Since industries vary widely in the amount of skill required of their workers, and since the industrialization of non-industrialized countries requires the importation of "know-how" and skilled technicians and the gradual development of a skilled labor force, it is essential that emphasis be placed initially upon industries requiring relatively little skill. The skill-factor is low in a number of industries that make relatively little use of capital (e.g., textiles, footwear, rubber manufacture, glass, etc.) and supply consumer wants of high priority. This factor is low also in a number of industries in which investment per worker is around or above average and which either make use of local raw materials (e.g., fertilizers, butter-making, soap, cement, sugar-refining) or provide products of great significance for industrialization (e.g., steel production). The lowness of the skill-factor in this second group of industries may enable relatively backward countries to develop them early inasmuch as the relatively low wage that may initially be paid to the less skilled workers offsets the relatively high cost

[38] For example, in Palestine in 1937 and 1946, respectively, 34 and 26 per cent of all industrial capital was invested in power stations and electrical appliances, with a capital investment of $10,000 per worker in 1942 compared with a capital investment of $1,900 per worker for all Jewish industry. See *Investing in Israel*, 14, N. Y., Jewish Agency for Palestine, 1949.

[39] In the *Report on seven year development plan for the plan organization of the imperial government of Iran* 1: 8–12, N. Y., Overseas Consultants, Inc., 1949, three principles are emphasized: (1) "national development effort must first be applied near the bottom"; (2) "capital is not a substitute for skill or experience"; and (3) "co-ordination is an essential ingredient of the plan." This is a very detailed and illuminating study of the problems of an under-developed country.

[40] For estimates of the amount of investment required per worker or job in various industries and countries see Mandelbaum, *op. cit.*, 35, 36, 95; Brown, *op. cit.*, 30–31; Buchanan, *op. cit.*, 25 ff.; Hilgerdt, *op. cit.*, 47–55; Ezekial, *op. cit.*, 24–26; p. 14 of the study cited in note 38; Perloff, H. S., *Puerto Rico's economic future*, 361–366, Chicago, Univ. of Chicago Press, 1950; Clark, *Conditions*, 71, 80; Bliss, C. A., *The structure of manufacturing production*, chap. 3, N. Y., Natl. Bureau of Econ. Research, 1939; Spiegel, H. W., *The Brazilian economy*, 231, Phila., Blakiston, 1949; Rosenstein-Rodan, P. N., Problems of industrialization of eastern and southwestern Europe, *Econ. Jour.* **53**: 210, 1943; Guyol, N. B., *op. cit.*, 6–10; Chang, *op. cit.*, 216; United Nations, *Economic survey of Latin America*, 1948, 16, Lake Success, United Nations, 1949.

of capital and skilled and technical labor.[41] In short, therefore, while it is not possible to substitute capital for training and experience, it is possible already to use considerable capital even when the number of skilled workers is relatively small.

(5) Just as industrial progress initially calls for the economical use of such scarce agents as capital and skilled labor so also does it call for the exploitation of relative abundant natural resources. This means that in countries in which population is sparse landed products must be duly emphasized, while, in countries in which land is scarce, raw material resources must be exploited, particularly since these are the most likely sources of the foreign exchange needed for the importation of equipment and know-how and the maintenance of foreign debt service. In general, this emphasis, which one would expect competitive forces to bring about, has characterized both foreign investment in under-developed countries and the progress of domestically financed industry.[42]

(6) Because of the linkages that obtain between various industries, it is essential that each be developed in proper proportion to the others, given prevailing external trading relations. For if this is not done, either some industries will be characterized by excess capacity, or inter-industry complementarities will not be fully exploited. This rule cannot be fully carried out, however, since certain industries such as public utilities and certain forms of investment such as highways and transportation, not being nicely adaptable to current requirements, often must be built up ahead of demand. Leontief's methods appear well suited to disclose the complementarities referred to and the course of their development.[43]

V. THE DEVELOPMENT OF THE LABOR FORCE

Industrial progress presupposes a healthy, adequately trained, and sufficiently motivated labor force. Industrial development programs therefore require action on the health, the training, and the motivation fronts.

(*a*) Health. In most of the under-developed countries diets are quantitatively and qualitatively inadequate, and preventable forms of infectious and contagious disease afflict unduly large fractions of the population and reduce both their capacity and their desire to engage effectively in economic activities. Accordingly, steps must be taken both to correct dietary deficiencies and to bring preventable diseases under control before industrialization can progress far in any country, in part because the spread of disease (whether of man, animal, or plant) is greatly accelerated by the intensification of communication consequent upon industrialization and economic development. The steps indicated as necessary involve quantitative and qualitative improvements in food supply and diet, the importation of necessary medicines, the training of an initially sufficient number of medical technicians and workers, the organization of effective public health programs, and so on.[44]

[41] On labor requirements by representative types of industry see Brown, *op. cit.*, 30–33. On time required to learn job in the United States see War Manpower Commission Bureau of Manpower Utilization, *Training grades for selected occupations*, Washington, 1943, and National Resources Planning Board, *Industrial location and national resources*, chap. 11, Washington, Natl. Resources Planning Board, 1943. While wage structures appear to be somewhat affected by the amount of equipment used per worker, they also appear to reflect differences in the degree of skill, etc., required, by industry. In so far as this is the case types of industry that are low on the wage structure scale probably are well suited to newly industrializing countries unless they require materials not readily accessible. On the wage structure see, for example, Lebergott, S., Wage structures, *Rev. Econ. Statistics* 29: 274 ff., 1947.

[42] See note 28 above. Hoffmann found that whereas labor-oriented consumer-goods industries predominated in countries in which labor was relatively plentiful, material-oriented necessity producing industries developed in a number of countries producing the necessary raw materials. Iron and machine industries predominated where the raw materials were to be had. See *op. cit.*, 134 ff., 164. In Latin America 78 per cent of the raw materials used in manufactures are of local origin. See United Nations, *Economic survey of Latin America*, 23–24, Lake Success, United Nations, 1949. As industrialization progresses in a country, its industries and output become relatively more capital intensive. See Bonné, A., *State and economics in the Middle East*, 222, London, Kegan Paul, Trench, Trubner & Co., 1948.

[43] E.g., see Leontief, W. W., Exports, imports, domestic output, and employment, *Quart. Jour. Econ.* 60: 171–193, 1946. On inter-industry linkages see National Resources Planning Board, *Industrial location and national resources*, chap. 5.

[44] Data presented in table 1, lines 19–21 and 23–26, and table 3, columns 7–11, indicate that in the under-developed countries life expectancy is quite low, t.b. mortality is high, the number of physicians is far from adequate, and diets are so defective, quantitatively and qualitatively, as to impair the productive effectiveness of the labor force and reduce its resistance to disease. Illustrative of the incapacitating effects of ill health in the under-developed parts of the world are these: malaria affects 300 million persons per year, killing 3 million and causing a loss of 20–40 days per person afflicted per year; schistosomiasis, a debilitating rural disease like malaria, afflicts 20–30 million people in the Near East alone and millions more in Africa, Asia, and Latin America; filiarsis cases number about 189 million per year

(*b*) Education and industrial training. Illiteracy and lack of industrial training characterize most of the non-industrial populations. Yet a certain amount of education and industrial training is essential to the initiation of an industrialization program. Adequate provision must therefore be made for such education and training.[45]

(*c*) Motivation. Industrial progress is impossible in the absence of a well-organized system of motives, incentives, and social pressures that impels men to work hard and effectively. Moreover, such a system must be elastic, so that, as output per worker rises, the system's compulsion increases, with the result that the representative member of the labor force remains disposed to work almost as many hours per year as he did prior to the enlargement of his output and income. Such a system is not easily introduced into a culture that is not already shot through with at least potentially appropriate motives and incentives. Furthermore, a diversity of means must be employed to introduce suitable systems of motives, incentives, and other social pressures, since the cultures of under-developed countries are heterogeneous, ranging from the complex cultures of essentially independent Oriental and Latin-American countries through the somewhat dualistic cultures of societies long under colonial rule (even though recently "liberated") to the less complex cultures of some of the African and Oceanic peoples. In fact, if only some Western methods are introduced into a non-industrialized area, and jointly with conditions of the sort long associated with "colonialism," the outcome may resemble proleterianization much more closely than incentive-impregnated industrial development.

Following Moore we may classify under four heads the courses of action essential to the development of an adequate motivational system. (i) Barriers to industrial employment must be removed. These include besides sheer ignorance of the industrial way of life, attachment to pre-industrial forms of social and economic security and a lack of interest in the attributes of status and prestige characteristic of industrial societies. (ii) Propellants toward industrialization must be supplied. Agricultural overpopulation is such a propellant as is the destruction, by external competition, of the markets hitherto existing for the skills of pre-industrial craftsmen. Political and economic coercion and the imposition of taxes and other burdens that must be paid in cash, together with the discriminatory impact of local customs, operate individually and in combination to press adversely affected individuals to engage in industry. (iii) The attractions of industrial employment must be magnified. Of paramount importance is the introduction of a money economy, together with the corollary condition that money serve both as the primary symbol of prestige and as the principal means by which men can obtain the things which they prize. Opportunity to increase and use industrial skill is quite important also. Industrialization is more likely to progress rapidly in a society with a well developed state apparatus than in one without a well-organized state, since industrial progress is essential to a state's realizing its political and its military aspirations. Industrial employment may prove attractive to individuals also if it is conducive to

in under-developed countries; yaws, widespread in tropical countries, afflicts over one million in Haiti alone; hookworm and other intestinal parasites debilitate millions; cases of syphilis number 20–100 millions and those of gonorrhea 2–3 times as many. There is high incidence also in many under-developed countries of diseases accompanied by high mortality (e.g., smallpox, typhus, cholera, plague, kala-azar, some fevers) or by disability (e.g., trachoma, leishmaniasis). Finally, in many under-developed countries infant mortality is very high (e.g., over 500 per 1,000 births in Iran). Yet, every one of the diseases mentioned can be virtually eliminated at relatively small cost through a three-fold attack: (*a*) insect control, general sanitation, and reduction of contact between infected and non-infected persons; (*b*) use of vaccines, etc., to prevent infection; and (*c*) use of drugs and medicines to cure victims and remove reservoirs of infection. It appears that, of the various conditions prerequisite to industrialization, the one that can be attained with most speed and economy is a relatively satisfactory state of health. For an excellent and detailed account of the existing state of health and the means of improving it in a representative under-developed country see volume 2 of the work on Iran cited in note 39 above. On the incidence of disease and methods for its control see United Nations, *Technical assistance for economic development*, 25–26, 243–308; U. S. State Department, *Point four*, 150–156. Concerning the influence of industrial development upon the diffusion of disease see Furnivall, J. S., *Colonial policy and practice*, chap. 10, Cambridge, Univ. Press, 1948. It may be noted, for purposes of comparison, that in the United States in the winter of 1935–1936, 2–3 per cent of the population of working age were disabled on a given day. See Dublin, L. I., and Lotka, A. J., *The money value of a man*, 113–114, N. Y., Ronald Press, 1946.

[45] On the high incidence of illiteracy, together with the comparative lack of means of communication and diffusion, in the under-developed countries see table 3, columns 3–6, and table 1, lines 14–17. An effective educational program entails more than the elimination of most illiteracy; it requires also the development of technical schools and the gradual formation of a technically competent labor force. See volume 2 of work on Iran (cited in note 39 above) for practical ways of solving the educational problems of an under-developed country.

individual social achievement, or if it promises a greater amount of individual freedom than is possible in a non-industrial society.

(iv) After the individual has been drawn into an industrial system it is essential both to keep him there and to impel him to be active. This calls for an appropriately advancing wage-level, for the inculcation in the individual of aspirations which material rewards can effectively and uniquely satisfy, and for appropriate recognition of those job-oriented incentives which nonmaterial rewards are best suited to satisfy. Other steps are also in order: encouragement of the individual worker to acquire skill; effective imposition of industrial discipline; avoidance of ostensible inter-individual or intergroup inequities and discrimination; replacement of pre-industrial by adequate industrial forms of economic and social security; and integration of the individual into a system of culture that makes the enhancement of his satisfaction dependent upon industrial progress.[46]

Of the various courses of action that must be pursued if an under-developed country is to be industrialized, none is more amenable to assistance from abroad and to action by the state than are (*a*) and (*b*) under V. The state, moreover, may contribute in considerable measure to the creation of a system of motives, incentives, and pressures suited to adapt individuals to an industrial mode of life and enable them to function effectively thereunder. While such action on the part of the state necessarily entails an initial reduction of consumer and worker sovereignty and choice, it probably is much more defensible than the very marked restriction of consumer sovereignty that appears to be necessary if densely populated countries are to supply enough capital internally to industrialize themselves at comparatively high rates.

VI. EXCHANGE RELATIONS, INDUSTRIALIZATION, AND INTERNATIONAL INCOME DISPARITY

At present international disparity in income per capita is very marked, with per capita income in the United States 15–30 times as high as that in non-industrialized countries. In this section, therefore, we shall inquire whether international income disparity is likely to be reduced in the future.

Empirical data suggest that income disparity has increased both at the national and at the international level in the past hundred years. In the United States in 1945, for example, the level of farm living in the highest Iowa counties was 12–39 times that in the lowest Kentucky counties. It is unlikely that so great a discrepancy between two long-settled agricultural counties prevailed a century ago. Per capita output apparently has increased more rapidly in the United States and other advanced countries in the course of the past century than in under-developed countries. For example, during comparable periods output per man-hour has risen more rapidly in industrialized than in non-industrialized countries, and in the United States than in continental Europe and Asia, with only newly-developing South Africa, Japan, and parts of South America and Europe (i.e., Belgium, Czechoslovakia, and Latvia) temporarily experiencing higher rates of growth. Thus, whereas the American level was 11–13 times the Indian level and 30–40 times the Chinese level in the 1940's it was only about 9 times the Indian and Chinese levels in 1860.[47]

International isolation makes for disparity whereas international intercourse makes for its reduction. For in the absence of relatively free international economic and cultural intercourse, the income-increasing forces manifest relatively more momentum in countries already developed and industrialized than in countries in which industrialization has made little or no headway.

Given a persistingly satisfactory combination of the following circumstances, international income disparity would be greatly reduced: (*a*) an appropriate international distribution of land, natural resources, and technological knowledge; (*b*) unrestricted international trade in productive agents, goods, and services; and (*c*) freedom on part of the population to move internationally and maintain a suitable distribution of population. It is not likely, however, that within the calculable future (*a*) and (*c*) will prevail in suffi-

[46] These two paragraphs are largely summaries of W. F. Moore's two studies: Primitives and peasants in industry, *Social Research* 15: 44–81, 1948, and Theoretical aspects of industrialization, *ibid.*, 277–303. On the effects of cultural pluralism see Furnivall, J. S., *Netherlands India*, chap. 13, Cambridge, Univ. Press, 1939.

[47] The data used in this paragraph are from Clark, *Rev. of Econ. Progress*, 1 (4): 2, 1949; Hagood, M. J., *Farm operator family level of living indexes for counties of the United States 1940 and 1945*, Washington, U. S. Dept. of Agriculture, 1947. On the causes of the persistence of poverty within agriculture and on their similarity to the causes of the persistence of international poverty see Schultz, T. W., Poverty within agriculture, *Jour. Polit. Econ.* 58: 1–15, 1950.

cient measure to permit freedom of international trade to correct most of the remaining disparity.[48] Migration will be less free than in the past. Only technological knowledge will become more evenly distributed. Restrictions upon competition and freedom of trade, while they probably will be less marked than in the 1930's, are not likely to be reduced to their pre-1914 dimensions.

Despite these difficulties, it is possible that the spread of industrialization will appreciably reduce international income disparity. Judging by past tendencies per capita income may advance about 1.5 per cent per year in countries presently industrialized. In 50 years such a rate will elevate current incomes of $500, $1,000, and $1,500, respectively, to $1,053, $2,105, and $3,158. Now suppose that S and s remain fairly constant for 50 years in countries presently under-developed and that per capita income there rises 2.5–4 per cent. Given a 2.5 per cent rate, incomes of $75, $100, and $150 will rise, in 50 years, to $258, $344, and $516. Given a 3 per cent rate and the corresponding figures are $329, $438, and $658; and given a 4 per cent rate, $533, $711, and $1,066. In short, if per capita income advances 2.5 per cent per year for 50 years in under-developed countries, given a 1.5 per cent rate of increase in industrialized countries, the disparity between the two types of countries will be reduced about four-tenths; if 3 per cent, about one-half; and if 4 per cent, about seven-tenths.

Realization of such a reduction in international income disparity presupposes a considerable increase in the volume of exports moving out of countries undergoing industrialization. For this there are two reasons. First, since a country undergoing industrialization must long import scarce technical services, equipment, and other needed physical assets from abroad, it must convert a part of its domestic savings into foreign exchange wherewith to purchase equipment in industrial countries. Second, eventually, when such a non-industrialized country's foreign borrowing falls short of its service charges on past foreign borrowings, it must meet the difference through net exportation.

For purposes of illustration let us suppose a country of 1,000,000 inhabitants who increase 1 per cent per year and produce an annual income of $100 million in the base year. Assume further that s has a value of 0.4; that national income increases 4 per cent per year, and per capita income 3 per cent per year; that imports of physical equipment aggregate 5 per cent of national income each year, of which half are paid for through foreign borrowing and half through the conversion of domestic savings into foreign exchange; that the service charge on each increment of foreign investment amounts to 8 per cent per year for 20 years, upon the expiry of which the loan may be considered amortized; and that consumer imports which do not directly or indirectly augment the capital stock remain fixed at $10 million per year. Under the conditions given annual investment must aggregate 10 per cent of the national income, of which 7.5 per cent is provided out of domestic sources and 2.5 out of foreign. Since, with s equaling 0.4, an annual increment of investment amounting to 10 per cent of the national income increases national income by 4 per cent, 0.25–0.35 of which probably is imputable to capital, such increment produces and earns more than enough income to cover service charges of 8 per cent. For, whereas the income produced and earned by the assumed annual increment of investment ranges between 1 and 1.4 per cent of the national income, the service charges amount to but 0.8 per cent of the national income. The principal problem, therefore, is that of transforming one-half of the service charges on the annual increment in wealth into foreign exchange. It is assumed throughout, of course, that all investment expenditures labeled as such, whether domestic or foreign, are actually income-increasing investment, with every increment of 2.5 units of investment being accompanied by an increment of 1 unit of income. It is also assumed, despite some of the contrary facts presented, that scarcity of land and/or natural resources will not operate as a limitational factor.

In the first year, with national income equal to $100 million, we require $12,706,000 of foreign exchange: $10 million for consumer imports, $5 million for capital imports, and $200,000 for for-

[48] P. A. Samuelson has recently shown that international trade not only reduces international differences in factor prices (as economists have long held) but, under certain conditions, can eliminate them. These conditions not being realizable in reality, it follows only that international trade may in some measure reduce international differences in factor prices consequent upon international differences in factor equipment. See International factor-price equalization once again, *Econ. Jour.* **59**: 181–197, 1949, and International trade and the equalisation of factor prices, *ibid.* **58**: 163–184, 1948. The removal of tariffs and the establishment of larger free-trade areas will not benefit, and probably will injure, the less-developed components of such area in the event that essentially free competition does not obtain *within* the area. See Rothschild, K. W., The small nation and world trade, *ibid.* **54**: 26–40, 1944.

eign debt service, against which may be set $2.5 million foreign borrowings. While the absolute amount of foreign exchange required increases as the years pass, it increases less rapidly than the national income under the conditions given, falling from 12.7 per cent of the national income in the first year to about 9.1 per cent in the twenty-fifth year. This percentage approximates 10.4 in the sixteenth year when for the first time aggregate service on the foreign debt approximates annual foreign borrowings, thereafter to exceed them. If we hold consumer imports constant at $5 million instead of $10 million, the amount of foreign exchange required, expressed as a percentage of the national income, remains in the neighborhood of 7.7 until the twentieth year (when the last payment is being made on the first foreign loan) and thereafter declines slightly. If, consumer sovereignty being assumed, consumer imports rise (say) half as fast as the national income, the amount of foreign exchange required, expressed as a percentage of the national income, remains in the neighborhood of 12.7 until the twentieth year when it begins to decline slightly. These figures rest, of course, upon the assumption that all foreign exchange except that used for debt service and the stipulated consumer imports is utilized to purchase income-producing agents, with s remaining constant at 0.4.

In view of what has been said, the industrialization of the under-developed countries can proceed as has been assumed only if they can obtain enough foreign exchange to meet their expanding needs for equipment and for rising aggregate foreign debt-service. Yet, for reasons to be indicated, it is likely that, in the absence of outright gifts from the industrial to the non-industrial countries, a sufficiency of foreign exchange will not be forthcoming. If this be the case, the borrowing countries will not be able to service their foreign debt,[49] foreign sources of loan funds will contract, and the rate of progress of the non-industrial countries in industrialization and income will fall to a level not much above that obtaining in the countries already industrialized. This tendency will be accentuated if, as has been suggested, a shortage of crucial natural resources operates to reduce the value of s below the level of 0.4 assumed.

The availability of foreign exchange (against the industrialized equipment-supplying countries) to the non-industrialized equipment-purchasing countries will be governed principally by two circumstances: (*a*) the ratio of income growth in the former to that of output-growth in the latter; and (*b*) the terms of trade obtaining between the two sets of countries. Condition (*a*) tends to be unfavorable to exchange availability, while condition (*b*) may be rendered favorable, but probably not enough so to offset (*a*).

(*a*) By assumption, aggregate income will grow only about half as fast in the industrialized countries as will aggregate output and income in the non-industrialized countries. Accordingly, in the absence of significant changes in the relation of the price structures of non-industrialized countries to those of industrialized countries, the aggregate monetary demand of the latter countries for the products of the non-industrialized countries will not grow as fast as will the aggregate demand of the latter countries for the products of the former. In consequence, an increasing shortage of foreign exchange will develop in the non-industrialized countries; and this shortage, while reducible, will not be eliminatable through the development of tourism, inasmuch as tourists favor the more industrialized countries. (*b*) Since the demand of industrial countries for the products (principally raw materials and labor-embodying fabricated goods) of non-industrialized countries tends to be inelastic in terms of price, advances in the export prices and consequently improvements in the terms of trade of non-industrialized countries may operate to increase the income and improve the exchange position of such countries. The future may bring such improvement,[50] and it may be accentuated, as we indicate below, by state action.

[49] When, under circumstances such as are described above, default takes place, its cause is, not the nature of the foreign investment, but the inability of the borrowing country to sell enough goods and services. On why defaults tend to occur see Buchanan, *op. cit.*, 115–116. Difficulties attendant upon an under-developed country's obtaining a sufficiency of foreign exchange may be accentuated also by the fact that the spread of industrialization may undermine such international division of labor as has been inherited from the past without replacing it by a new international division of labor that is adapted to the new circumstances. For example, see Rahmer, B. A., Note on the industrialization of backward areas, *Econ. Jour.* 56: 657–662. On the purported and the actual structure of international trade see Hirschman, A. O., *National power and the structure of international trade*, chap. 6, Berkeley, Univ. of Calif. Press, 1945. See also next note.

[50] On the past and the prospective course of the terms of trade, see Clark, *Conditions*, chap. 14, and *Economics of 1960*, chaps. 4, 7. For some 50 years prior to 1939 the terms of trade were turning against the suppliers of primary goods and in favor of countries exporting manufactures, the

In our discussion so far we have assumed a somewhat higher amount of foreign investment and foreign importation than appears warranted. Earlier it was inferred that, since considerably more than one-half of a nation's income-producing wealth is immobile, it ought to limit its annual foreign borrowing to something like one-fourth of its total annual investment. It would appear advisable also that a country draw less than half of its actual annual increment of capital from foreign sources if this be possible. In our earlier example we assumed that foreign-produced equipment and foreign borrowing amounted to 5 and 2.5 per cent, respectively, of the national income each year, with foreign borrowing supplying a rising proportion (16.4 per cent in the first year and 21.3 in the twenty-fifth year) of the gross foreign exchange requirement. If foreign borrowing and foreign equipment purchases are cut to 1.25 and 3.75 per cent of national income, respectively, net foreign exchange requirements grow less rapidly even though foreign borrowing now supplies only about two-thirds (9 instead of 16 per cent the first year, and 14 instead of 21 the twenty-fifth year) as large a fraction of the gross foreign exchange requirement as formerly. The ratio of foreign exchange requirements to income, virtually the same under both conditions in the initial year (i.e., 12.7 and 12.6 per cent), falls somewhat more rapidly under the new assumptions (approximating 7.8 instead of 9.2 in the twenty-fifth year). It is open to question, of course, whether in its early developmental stages a non-industrialized country investing the equivalent of 10 per cent of its income annually can produce 6.25 tenths of this increment locally and rely upon foreign sources for but 3.75 tenths, as our new assumptions require.

In view of what has been said, several inferences may be drawn in respect of exchange relations. (*a*) Foreign borrowing and foreign equipment purchases probably should supply somewhat less, respectively, than one-fourth and one-half of the annual increment of capital. (*b*) Since the demand for their products tends to be inelastic, non-industrialized countries may employ appropriate measures (e.g., tariffs, export taxes) to improve their terms of trade with industrialized countries. For such action, while it may operate directly, by reducing import prices relative to export prices, to retard the development of some domestic manufactures,[51] will also operate indirectly to stimulate industrialization by making available a larger amount of foreign exchange than otherwise would be on hand for the purchase of equipment abroad. (*c*) It is essential that non-industrial countries restrict consumer sovereignty by installing foreign-exchange and related controls, curbing the importation of foreign-produced non-essentials, and appropriating virtually all available foreign exchange for the purchase of foreign equipment and the payment of foreign debt service. (*d*) In the event that foreign funds and equipment are to be had more cheaply if the government of an under-developed country acts as principal, or as agent for its private entrepreneurs, then such action is indicated (provided that, of course, there are not generated other costs which more than offset the gains attendant upon such governmental action).

VII. ILLUSTRATIONS AND PROSPECTS

In this section we shall do two things. (i) We shall illustrate by example how industrialization has progressed in some countries and how it has been retarded in others. (ii) We shall show that present plans for industrialization usually assign a much larger role to the state than was the case in the nineteenth century.

(1) *Japan.*[52] The uniquely remarkable indus-

purchasing power of primary goods falling about two-fifths in the course of this period. This trend adversely affected under-developed countries, the bulk of whose exports necessarily consist of primary commodities. Since the late 1930's the exchange value of primary exports has risen, in terms of manufactured imports, about one-tenth. Whether this trend will continue, however, is not certain, particularly in view of the fact that considerable new foreign investment may flow, as in the past, into the production of primary commodities. See United Nations, *Relative prices of exports and imports of under-developed countries*, 7–8, 127, Lake Success, United Nations, 1949.

[51] On this point see Metzler, L. A., Tariffs, the terms of trade, and the distribution of national income, *Jour. Polit. Econ.* **57**: 17–25, 1949.

[52] On output per man-hour in Japan and other countries discussed in this section see Clark, C., Levels of real national product per man-hour, *Rev. Econ. Progress* 1 (4): 2, 1949. On Japan's income see Schumpeter, E. B., ed., *The industrialization of Japan and Manchukuo, 1930–1940*, 16, N. Y., MacMillan, 1940, and Clark, *Conditions*, 116, 124–125. On savings see *ibid.*, 406. On investment see Staley, *op. cit.*, chap. 4 and appendix. On Japan's foreign investment, economic development, etc., see Moulton, *Japan*, and Reubens, E. P., Foreign capital in economic development: A case-study of Japan, *Milbank Memorial Fund Quart.* **28**: 173–190, 1950. (In 1872 Japan's population already numbered about 730 per square mile and about 1,500 per square mile of productive land.) By way of contrast with pre-1940 Japan the Philippine economy has wasted much of the approximately $2 billion poured into it

trial progress of Japan is illustrative both of the extent of accomplishment possible and of the comparative unsurmountability of the obstacles to be overcome when a nation's internal resource equipment is poor. Japan's industrialization program may be said really to have begun in 1868, at which time the nation was still essentially feudal, internationally isolated, overpopulated, and lacking much of the institutional equipment essential to industrialization. The potential strength of the national government rapidly materialized, however; interclass relations were kept stable; and the population manifested a striking disposition to learn, work, save, and otherwise carry out the government's industrialization program. The government, moreover, offset the lack of an adequate entrepreneurial class by performing many of the functions of this class and facilitating the accomplishment of others through the use of appropriate monetary, fiscal, and related policies. By 1930 the relative number of workers engaged in agriculture and fishing had fallen to about 50 per cent from an estimated 85 as of 1873. Even so output per man-hour apparently did not begin to rise above the Oriental level of 3 cents an hour until the close of the nineteenth century, when it began to climb 4.5 to 5 per cent per year to a level of 19–20 cents in the early 1940's. During this 40-year period output per worker rose slightly more than 4 per cent per year, while the population increased about 1-1/4 per cent per year (in contrast with an annual increase of about 7/8 per cent in 1872–1900). Despite its high rate of growth Japan's output per man-hour in the early 1940's still only approximated that attained in the United States by 1825, in Britain by 1850, and in Germany by 1870.

Japan had relatively little assistance from foreign investment. In the early 1870's net foreign investment approximating a little over one per cent of the then national income was contracted, but this was liquidated by 1896. Between 1896 and 1913 net foreign investment increased, the average annual increment approximating something like 2–2.5 per cent of the average annual income during that period. By 1929, largely as a result of the favorable effects of World War I, net foreign investment was reduced one-third below the 1913 level. By 1938 Japan had become a net creditor nation to the extent of $534 million (i.e., about 8 per cent of the 1938 national income).

Apparently Japan was able to develop industrially, despite its small and dwindling net influx of foreign capital and its lack of natural resources, because it sold, saved, invested, and spent wisely. And it was able to do these things because it had economical access to foreign markets for its products and to foreign sources of supply for the things its industries lacked. Clark estimates Japanese savings in 1900–1940 at about one-fifth of the national income while Staley estimates investment to have varied between 10 and 17 per cent of the national income. Judging from the rate at which income progressed, the rate of investment probably lies between these two estimates. In any event it was high, given the lowness of per capita income. (Even so, investment per capita per year rose in 1936 dollars from only about 1.67 in 1900–1909 to about 5.25 after 1920, which is but a fraction of the $800–1,300 required in the middle 1930's to equip a worker in manufactures.) The foreign exchange provided by foreign loans initially was multiplied a number of times and subsequently was replaced by the expanding sale of Japan's predominantly labor-embodying products. This exchange was used, moreover, almost exclusively for the purchase of foodstuffs for the working population and for the procurement of raw materials, semi-finished products, and equipment essential to industry. Even in the absence of war Japan could not have continued to progress so rapidly had her government become weak, her inter-class relations instable, her working population less industrious, and her income-receivers less disposed to save.

(2) *India.*[53] The industrial history of India is probably more typical than that of Japan of development in an Asiatic country marked by a nonprimitive and ancient culture. Although

since the close of the war, with waste characteristic of both the private and the public sectors of the economy. In view of the experience of the Philippine economy, it is questionable whether, in the absence of a strong and prudent government, foreign aid can contribute much to industrial development. See *The Banker's Magazine*, 246–247, March, 1950.

[53] On India's income see Clark, *Rev. Econ. Progress* 1 (5): 1–3, 1949. On past investment see Lewis, *op. cit.*, 335. On India's supposed capital requirements (which are generally put too low) see Staley, *op. cit.*, chap. 4; Harris, S. E., *Economic Planning*, chap. 11, N. Y., Knopf, 1949; Iyengar, S. K., Industrialization and agriculture in India, *Econ. Jour.* 54: 189–205, 1944. Annual saving is put at 2–3 per cent of the national income in United Nations, *Methods of financing economic development in under-developed countries*, 73. At the close of 1949 India owned one-third of Britain's overseas debts, or about one billion sterling (*Fortune* 72, April, 1950).

nearly three-fourths of the occupied population remains in agriculture, its aggregate output is very low and inadequate for the nation's needs. Energy consumption per capita is less than 1.5 per cent of the American average. Although gross reproduction has always been high, the population has grown sporadically and at an average annual rate (about 5/8 per cent per year) only about half that observed in Japan. While India's resource equipment appears to be somewhat superior to that of Japan, its output and its wealth have grown less rapidly. Between 1860 and the early 1930's output per man-hour increased about 1-3/8 per cent per year from 3 cents to 8-9 cents, while output per occupied person increased just over 0.75 per cent per year between 1866 and 1944. Even so, output per man hour remains near or below the level attained in Britain in the late eighteenth century while the wage level appears to be appreciably below that realized around 1600 when India's population was only one-fourth as large as at present.

While capital is essential to India's industrialization, it is not evident at present that it will be formed at a sufficiently high rate. In the light of our earlier analysis and of the fact that India's population will probably grow at least 1 per cent per year, a 3 per cent per year increase in per capita income calls for investment at an annual rate of around 11 per cent of the national income. Staley estimates that should India develop during the next four decades as Japan did, it will require an investment of about 81 billion 1936 dollars, which would probably entail annual savings in excess of 10 per cent of the national income. These funds are not to be had from foreign sources, judging by the fact that outstanding foreign investment aggregated only about $7 per capita in 1938 and that, abstracting from India's acquisition during the war period of a sterling balance in excess of one billion, not much foreign capital is flowing into India. Neither is there evidence that domestic savings in India, recently estimated at 2–3 per cent of national income, will approach 10 per cent of the national income.

(3) *China.*[54] While China is as well equipped with natural resources as is India and better equipped than Japan, her industrial progress has been negligible, and her output per man-hour still remains at the 3-cent level attained in Germany before 1800. At present many obstacles stand in the way of China's industrialization. China has long lacked a strong government, good politico-economic institutions, political order, and social stability. Her population is dense, exceeding 100 persons per square mile in settled areas, with arable land per person averaging about 0.55 acres. If her population is not increasing at present, it still could easily begin to increase 1 per cent per year. Three-fourths of the population is engaged in agriculture where crop yields are so low as probably to be susceptible of a 50 per cent increase. Most important of all the obstacles to industrial progress is China's lack of equipment and her seeming inability to form capital at a high rate. In the late 1930's, at which time outstanding foreign investment in China approximated $6 per capita, *modern* industrial investment was estimated at about $2.50 per capita, while energy consumption per capita was but 1-1/4 per cent as high as in the United States and only about 7 per cent as high as in Japan. Data relating to 1930–1936 confirm the impression that capital formation is proceeding at a very low rate. For, during this period, foreign investment approximated 1.8 per cent of income; net investment, 1.3 per cent; and domestic investment, −0.5 per cent. The corresponding rates for 1936, the best year in the six, were 3.9, 5.5, and 1.6. According to Staley, should China develop in the next four decades as Japan did in 1900–1940, she will require, in 1936 dollars, 133 billions of capital, with the annual requirement rising from 1.36 billion in the first decade to $5.2 billion in the fourth. These figures must be increased at least one-half to allow for increases in the price level. If we put China's national income at $22.5 billion and assume that consumers' capital formation will absorb 2 per cent of the national income, we get a required saving rate of about 12 per cent per year. This rate, which might permit per capita income to rise close to 3 per cent per year is far above any recently observed sustained rate of investment.

(4) *Puerto Rico.*[55] The industrialization of Puerto Rico represents that of a very densely populated country (about 645 persons per sq.

[54] On foreign investments in China see Remer, C. F., *Foreign investments in China*, N. Y., 1933; Lewis, *op. cit.*, p. 334. The estimates of *modern* capital and capital needs are from Staley, *op. cit.*, chap. 4. Income data for 1931–1936 are reported in Ou, Pao-San, A new estimate of China's national income, *Jour. Polit. Econ.* **54**: 547–554, 1946, and United Nations, *National income statistics* 1938–47, 46–47, Lake Success, United Nations, 1948.

[55] On Puerto Rico, see Perloff, *op. cit.*, 162, 179, 186, 365–366.

mi.) poorly endowed with nonhuman resources and characterized by a high rate of population growth (2 or more per cent per year). Individual savings are small, representing about 2 per cent of income payments to individuals in 1940–1944, while net additions to the island's capital stock are small. Whence it is not likely that per capita income ($271 in current prices in 1946), which, under the impact of war, increased 42 per cent in real terms in 1940–1946, will continue to grow appreciably, unless population growth is effectively controlled, investment is greatly increased, and labor-oriented manufactures are developed.

(5) *Israel and the Middle East.*[56] Contrast of conditions in Israel with those in surrounding lands illustrates admirably what can be done, given capital, entrepreneurship, and a technically trained labor force. Israel's investment has more than kept pace with its population growth—some 160 per cent in 1938–1949—investment representing 40 per cent of the national income in 1949. There is an adequate supply of entrepreneurial ability, while the labor force resembles the American in composition. Income distribution is comparatively equal by Western standards, and the welfare of the working population is held paramount. The apparatus of state is well-developed and effective. In the remainder of the Middle East an opposite set of conditions prevails: most of the population, nine-tenths of whom live at the margin of existence, remain ineffectively engaged in agriculture; there are relatively few resourceful entrepreneurs and the apparatus of state remains primitive; and there is little saving and investment, the favored few squandering most of the foreign exchange that the export of raw materials and other products brings in. In consequence, while investment (about $2,500) and output per worker are appreciably below the American level, per capita income is 3–10 times as high in Israel as elsewhere in the Middle East, and it is rising.

(5) *Brazil.*[57] The industrialization of Brazil represents that of a country with a comparatively sparse though growing population, a West-European culture, limited resources other than land, a predominantly agricultural (i.e., 68 per cent) labor force, and a very low though apparently growing per capita income ($57 in 1944) and output per man-hour (7 and 11 cents, respectively, in 1940 and 1946). Capital formation is progressing at a very rapid rate if estimates are to be accepted as valid, investment forming 24–29 per cent of income payments to individuals in 1944, and a somewhat smaller fraction of the national income. Even so, capital per industrial worker is low, averaging around $500 in São Paulo. These investment estimates appear to be much too high. Moreover, should they approximate reality, it is not likely that Brazilian workers will long tolerate a situation permitting so high a rate of capital formation, howsoever salutary are its longer run effects.

(ii) Modern plans for industrialization almost invariably assign a large role to the state. In fact, contemporary emphasis upon "national planning" is in considerable measure an outcome of the failure of nations, given essentially *laissez faire* conditions, to form capital rapidly enough and do the other things that comparatively speedy industrialization requires. Needless to say, of course, the apparatus of state often has served to check industrialization, usually by perpetuating anti-industrial minorities in power and diverting potential savings from capital formation.

Under-developed and non-industrialized countries today encounter a hazard that was not so conspicuous prior to World War I, a hazard consequent upon the increase in the political power of the common man. The working populations of under-developed countries, having before them inklings of the high material standards and the degree of power attained by workers in industrialized Western countries, today are demanding a larger share of after-tax national income than was commanded by their nineteenth-century prototypes, and they are insisting upon spending most of this relatively heightened income for consumer goods and services. In consequence, saving and capital formation have been affected adversely.

The rise of this hazard, therefore, is imposing a new duty upon the state, that of compelling the population to form adequate amounts of capital. It has become evident that, so long as the masses enjoy both consumer sovereignty and consumer freedom of choice, under-developed countries undergoing industrialization probably will not be

[56] On Israel see *Investing in Israel* (cited in note 38 above) and *Economic Horizons*, monthly publication of the Jewish Agency for Palestine. On Israel and the Middle East see United Nations, *Final report of the United Nations Mission for the Middle East*, Part I, 34–41, Lake Success, United Nations, 1949.

[57] On Brazil see Spiegel, *op. cit.*, chaps. 2, 5, 14. On the standing of Brazil relative to that of other Latin American countries see United Nations, *Economic survey of Latin America, 1948.*

able to find at home enough capital to complete the process. It follows that, so long as individuals refuse to supply enough capital, consumer sovereignty must be curbed. The state must appropriate a considerable proportion of the national income (say one-fifth) and divert it into capital-forming activities, allowing the consumers freedom of choice only in respect of how they spend their after-tax income. The state can accomplish this objective through an appropriate combination of measures, ranging from taxation and exchange-control to differential pricing and the imposition of obligations to contribute in kind to the formation of collective forms of capital (e.g., highways).

Given that the government is strong enough and the apparatus of state is sufficiently developed to facilitate capital formation, an underdeveloped state still must make important choices. (*a*) It must not attempt to force the relative rate of capital formation so high that the aggregate supply of effort is diminished, for the diminution of this aggregate consequent upon attempts to elevate unduly the percentage of the aggregate diverted to capital formation may bring about a reduction in the absolute amount of capital formed per year. (*b*) Since capital formation entails the substitution of future want-satisfaction for present want-satisfaction, care must be taken lest social and economic welfare are significantly reduced through the adoption of oppressive policies that are intended to accelerate industrialization and capital formation. The methods employed by Soviet Russia in this respect, together with the experiences of the Russian people, highlight the issue here under consideration. While modern welfare economics cannot supply precise answers to the questions involved, it can indicate the kinds of arbitrary standards that must be employed if a workable balance between current and future requirements is to be maintained.[58] (*c*) State-dominated approaches to capital formation must not become so rigid that they operate to decelerate the dynamic forces which, together with capital formation, make for industrial progress in the long run.

The various plans that have been proposed and/or introduced in nations intent upon accelerating their industrialization almost invariably call for higher rates of investment than voluntary savings are likely to permit. The under-developed countries, in which live about four-fifths of the world's population, have estimated their annual investment needs, over a four year period, at $17 billion, of which about one-fourth is expected from foreign sources. This figure approximates 11 per cent of aggregate income of the underdeveloped countries, estimated at about $150 billion. Of the $17 billion, only about 7, of which 3 are expected from foreign sources, are reported for Africa, Asia, and Latin America. By contrast, the annual investment needs of the developed regions outside of North America have been estimated at $27 billion, or 18 per cent of an estimated income of $150 billion, with about $6 billion to be supplied by foreign sources. The United States and Canada, with an annual income of some $240 billion, are destined to supply the $9 billion required by but not obtainable in the remainder of the world.[59]

Inasmuch as these capital requirements, though less than the industrialization of the under-developed countries entails, are in excess of voluntary domestic savings, state action designed to increase savings will prove necessary. That such action will prove necessary is suggested also by the fact that the world, including North America, is not likely to supply the $8–9 billion required from foreign sources. Prior to World War II the amount of foreign investment supplied by *all* investing countries never exceeded $2 billion per year. Outstanding foreign investment approximated only $53 billion in 1938, or about $25 per capita, and only $9 billions more than in 1913–1914. In 1938 as in 1913 about 56 per cent of all foreign investment was situated in Europe, Oceania, Canada, Soviet Russia, and the United States, the per capita figure approximating $42 in 1938. American gross investment abroad totaled only $11.5 billion in 1938.[60] During and after World War II, however, American foreign "investment" increased greatly, averaging about $7.5 billion per year in 1946–1949, of which the

[58] On welfare economics and its degree of relevance to decisions concerning what is the most appropriate rate of industrialization for a country see the works of Bergson and Arrow, cited in note 5 above. In Russia in the late 1920's opinion differed greatly respecting how fast and in what manner Russia should industrialize. See Erlich, A., Probrazhenski and the economics of Soviet industrialization, *Quart. Jour. Econ.* 64: 57–88, 1950.

[59] The figures given in this paragraph are based upon United Nations, *Methods of financing economic development in underveloped countries*, 44–45, 52–56, 64, 73–77, 84–85, Lake Success, United Nations, 1949.

[60] Staley, *op. cit.*, 80; Lewis, *op. cit.*, 49–50, 296, 334, 338; United Nations, *International capital movements during the inter-war period*, 2. Lake Success, United Nations, 1949.

United States government furnished (in the form of grants, credits, and capital equipment) about $6.7 and private investors about $0.8 billion.[61] It is questionable whether, even in the not too likely event that political stability and creditor security are assured, so high a rate of American investment can be maintained and, assuming repayment of most investment made after 1952, serviced. For the dollar requirements of industrializing under-developed countries will be intensified by their high internal rates of investment; and their ability to obtain dollars will be made difficult by the fact that the demand of non-industrial countries for the products of industrial countries will tend to grow much more rapidly than will the supply of foreign exchange wherewith to purchase these products.

Data relating to foreign investment in Asia, Africa, and Latin America indicate that these regions are not likely to receive significantly large amounts of investment from investing countries in general or from America in particular. In 1938 outstanding foreign investment approximated $9 billion, or $72 per capita in Latin America; $4 billion, or $24 per capita, in Africa; and $10 billion, or $9 per capita, in Asia. In 1913–1914 roughly comparable figures were, in billions: Latin America, 8.5; Africa, 4.7; and Asia, 6. Of the $11,491 million of American foreign investments outstanding in 1938, $4,154 million were in Latin America and $1,155 million in Asia and Africa.[62] Since 1945 only a negligible amount of American government credits have been extended to these areas; and, while appreciable private investment has flowed into Latin America, not much has gone into Asia and Africa.[63] Of the estimated aggregate investment needs indicated by various plans, etc., only about one-sixth was destined for Asia, Africa, and Latin America.[64]

[61] Kerber, E. S., Foreign transactions of the U. S. Government in fiscal 1949, *Survey of Current Business* 29: 9, 1949, and Abelson, M., Private United States direct investments abroad, *ibid.*, 20. In 1941–47 the United States furnished loans, grants, etc. in excess of repayments to the extent of $63.3 billion, at an average annual rate of $9 billion. The Marshall Plan will have raised this figure above $70 billion by 1952, a figure in excess of the $53 billion of world foreign investment outstanding in 1938. On the factors competing for American savings see my Prospective population and income growth and fiscal policy, *Natl. Tax Jour.* 3: 36–63, 1950.

[62] Lewis, *op. cit.*, 49–50, 296, 322–323; United Nations, *International capital movements*, 2.

[63] See references cited in note 61 above.

[64] See p. 52 of reference cited in note 59 above.

It is evident, in view of what has been said, that neither prospective foreign investment, nor, given great consumer sovereignty, domestic savings will be of the magnitude required if industrialization is to progress in under-developed countries at a rate allowing per capita income to advance in the neighborhood of 3 per cent per year. This objective can be realized presumably only if state action is employed to step up the rate of saving and insure that savings and foreign exchange are utilized in a manner suited, given their volume, to maximize the rate at which needed capital is formed.

CONCLUSION

The contents of this paper are not easily summarized. They suggest certain conclusions, however, both for nations undergoing industrialization and for countries—particularly the United States—whence much of the required foreign capital, equipment, personnel, and know-how must be drawn. From the standpoint of the countries undergoing industrialization the following conclusions are indicated. Because of the many difficulties attendant upon industrialization and because of the limitedness of the resources available for this purpose, it is essential that an industrializing country pursue only those courses of action which are of strategic importance, given that country's stage of development, resource-equipment, and other relevant conditions. Because a country's industrial development of necessity depends largely upon its internal resources, industrializing countries must do everything possible to render their internal conditions favorable to industrialization. Because capital and know-how are in such short supply, each must at all times be used with economy, and every effort must be made to augment the supply of both. Initially great improvements must be made in conditions relating to health and motivation, and population growth must be brought under control.

For various reasons already discussed the state will have to assume a far greater role than it filled in respect of the industrialization of the Western world.[65] In addition, the state must provide a favorable environment for industrialization, insure continuity of the industrialization program, provide diverse forms of leadership, and, through cooperation with other governments and with the

[65] On nineteenth-century instances of deliberate industrialization see Aubrey, H. G., Deliberate Industrialization. *Social Research* 16: 158–182, 1949; also Hirschman, *op. cit.*,

various international bodies such as the United Nations, bring to its people the benefit of foreign planning, guidance, and assistance.[66] All this means that the apparatus of state of most of the under-developed countries will have to be greatly improved and adapted to the performance of new functions. And even then, the best that can be hoped for, supposing that the world remains at peace, is a significant reduction in international economic disparity.[67]

From the standpoint of the United States and the Western world in general, the most important conclusion is the following. We live in a world extremely short of resources, capital, and know-how. The amount of capital that the United States and other Western investing countries can supply, given present and prospective defense needs and rising social security requirements, is very limited, both absolutely and in relation to the real needs of the under-developed countries. The Western world is engaged in what promises to be for many years an intense and unremitting struggle with anti-Western forms of totalitarianism. It follows that the Western world, and the United States in particular, should invest its quite limited resources predominantly in regions which, because of their friendliness to Western values, their geographical situation, and other relevant strategic considerations, represent good investment risks. The Western world cannot afford to squander its limited resources either on its actual and/or potential enemies, or upon countries which, though essentially friendly, fail to make good use of these resources.

[66] Concerning what may be done see United Nations, *Technical assistance for economic development*, Lake Success, United Nations, 1949; also the work cited in note 59; also the reports of the International Bank for Reconstruction and Development. Illustrative of the kinds of change industrial development calls for are those indicated for the states characteristic of the Middle East and Islamic society. On this question and on the broader sociological implications of industrialization for the Middle East see Bonné, *op. cit.*

[67] It is of interest, in the light of current discussion of the Point Four program, that the need for a somewhat similar program was suggested by Col. E. M. House in a letter (June 26, 1914) to President Wilson. (My colleague, Professor E. M. Carroll, called this to my attention.) See Seymour, C., *Intimate papers of Colonel House* 1: 264–269, Boston, Houghton Mifflin, 1926. In essence House proposed that the capital-exporting nations agree on a plan to develop the undeveloped parts of the world, supply needed capital at "reasonable rates," and establish conditions making such loans "reasonably safe." Implementation was prevented by the Sarajevo assassination and its aftermath.

TABULAR APPENDIX

Tables 1–4 summarize the main reported and measurable economic and cultural differences between the relatively industrialized and the non-industrialized countries. In table 1 information is given for three categories of countries, classified on the basis of per capita income in 1939: (*a*) Upper, over $200; (*b*) Middle, $101–200; (*c*) Lower, $100 and below. Data are given for only 1,836 of the world's 2,170 millions of population, as of 1939. Presumably, however, nearly all of the 336 millions for whom data were lacking in 1939 fell in category (*c*). On the assumption that this was the case, the world's population was distributed as follows in 1939: (*a*) 361 millions; (*b*) 304 millions; and (*c*) 1,505 millions.

In tables 2 and 3 information is reported by country, and particularly for class (*c*) countries for which data are available. The United States stands at the top of class (*a*) and Argentina at the bottom. The Union of South Africa, Chile, and the USSR represent class (*b*). The remaining countries, beginning with Cuba, are in class (*c*). It should be noted that population growth is essentially uncontrolled in class (*c*) countries, whose potential rate of growth is high. It is controlled in class (*a*) countries, whose potential rate of growth is very low. It is either controlled or rapidly passing under control in class (*b*) countries.

In table 4 information is given by continent and subcontinent. While no per capita income data are reported by continent, fairly good measures of relative standing in respect of income are provided in lines 9, 10, and 13.

TABLE 1

ECONOMIC AND SOCIAL INDICATORS, BY COUNTRIES GROUPED ACCORDING TO INDUSTRIALIZATION *

Item	Country group		
	Upper	Middle	Lower
1. Per cent of world's population in 1939	17	14	69
2. Population per sq. km. in 1947 (range)	1–285	7–151	2–204
3. Per cent of population aged 15–59 years	[62–64]	[59]	[54–55]
4. Income per capita in 1939 (dollars)	461	154	41
5. Income per capita in 1939 (range in dollars)	201–554	101–200	22–100
6. Index of per worker income in 1925–34	[100]	[34]	[13]
7. Index of per capita income of farm population	100	39	8
8. Per cent of occupied populations in agriculture	[22]	[57]	[75]
9. Index of industrial equipment per worker	[100]	[39]	[11]
10. Energy consumed per capita per day (H.P.H.)	26.6	6.4	1.2
11. Miles of railroad per 1,000 sq. mi. of area	40	29	13
12. Annual freight carried per capita (ton miles)	1517	927	58
13. Line 12 ÷ line 11	37.9	32	4.5
14. Motor vehicles per 1,000 population	111	7	1
15. Telephones per 1,000 population	90	7	2
16. Per cent illiterate (population age 10 and over)	Below 5	20	78
17. Elementary school teachers per 1,000 population	3.98	3.42	1.76
18. State of population growth	Controlled	Controlled or transitional	Uncontrolled
19. Physicians per 1,000 population	1.06	0.78	0.17
20. Expectation of life at birth (years)	63	52	30–40
21. T.B. death rate per 100,000 population	64	143	333
22. Net annual textile consumption per capita (lbs.)	18.63	7.52	4.8
23. All foods: calories per capita per day	3040	2760	2150
24. Animal proteins, oz. per capita per day	1.6	0.9	0,3
25. Fats, oz. per capita per day	4.0	2.3	1.3
26. Typical per cent of calories of animal origin	[20–40]	[10–15]	[under 10]
27. Steel consumption per capita (kilos)	[100–500]	[25–80]	[10–20]

* Figures in brackets are for roughly comparable group of countries, or are estimates.

Sources: Lines 4–5, 7, 10–12, and 14–25 are from U. S. Department of State Publication 3719, *Point Four*, 103–113 (mean values), Washington, 1950. Lines 1–3 are based upon United Nations publications. Lines 6, 8, 9, and 26 are from my Some Aspects, *loc. cit.*, 261–265. Line 27 is roughly estimated from United Nations, *European Steel Trends*, 120–123, 132–136.

TABLE 2

ECONOMIC INDICATORS, BY COUNTRY

Country	Population (1947)		Income		Product per man-hour (highest yr.)	Miles railroad (per sq.mi. of area)	Energy consumed per day (H.P. hrs. per capita)	Energy reserves in tons of bit. coal per sq.km.	Arable land per capita (hectares)	Per cent of labor force in agriculture[e]
	Total (millions)	Density per sq.km.	Per worker 1925–34	Per capita 1939[d]						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
United States	144.0	18	$1,381	$554	$1.19	80	37.6	320,665	1.55	22
United Kingdom	49.5	203	1,069	468	.62	222	27.1	565,647	.11	7
Argentina	16.1	6	1,000	218	.44	23	5.0	5,750	1.68	(36)
Union of So. Africa	11.6	10	276	188	.15	30	10.1	172,152	[.46]	26 [75][f]
Chile	5.5	7	550	174	—	20	10.7	12,724	0.26	(36)
U.S.S.R.	200.0	9	320	158	.18	14	6.8	62,034	—	67
Cuba	5.1	44	—	98	.20	70	2.6	—	0.39	(41)
Yugoslavia	14.8	58	330	96	.14	72	2.1	45,802	—	79
Poland	23.8	76	352	95	.19	89	5.6	250,981	.54	65
Japan	78.0	204	353	93	.20	102	6.6	109,052	0.07	52
Venezuela	4.4	5	—	92	.21	2	5.1	14,375	—	(51)
Egypt	19.2	20	325	85	—	9	1.7	1,881	0.31 –	67
Palestine	1.9	72	360	81	.19	30	1.0	—	—	31
Algiers	8.5	4	300	—	—	—	2.2	267	—	—
Turkey[a]	24.1	25	200+	(100–125)	.11	—	1.1	[3,720]	.51	82
Morocco[b]	11.5	20	200+	—	—	—	0.8	1,700	—	—
Costa Rica	0.8	15	—	76	—	22	1.4	—	—	—
Colombia	10.5	9	—	76	.08	5	1.5	10,521	0.26	(74)
Peru	7.9	6	—	72	—	4	1.1	11,569	0.25	(62)
Panama	0.7	10	—	71	—	17	12.3	—	—	(52)
Ceylon	6.9	104	—	63 (91)	—	38	1.4	Negligible	0.20	(62)
Mexico	23.4	12	360	61	—	19	2.2	9,221	0.28	(65)
Uruguay	2.3	12	650	56	—	26	3.2	4,701	0.43	—
Iran	17.0	10	—	(85)	—	—	0.8	5,929	—	76
Dom. Republic	2.2	43	—	51	—	8	0.5	—	—	High
Haiti	3.6	127	—	50 (36)	—	14	0.4	—	—	High
Nicaragua	1.1	8	—	50	—	4	0.7		—	(73)
Guatemala	3.6	33	—	48	—	17	0.6		—	—
Bolivia	3.9	4	—	47	—	5	0.3	26,259	—	—
Honduras	1.2	8	—	45	—	17	1.4		—	—
El Salvador	2.0	60	—	45	—	30	0.6		—	—
Brazil	47.6	6	435	46	.11	6	1.9	8,607	0.33	(67)
Ecuador	3.4	12	—	44	.11	7	1.0	9,694	—	—
Paraguay	1.2	3	—	39	—	4	0.6	12,795	—	—
Afghanistan	12.0	18	—	(50)	—	—	0.2	2,254	—	—
Ethiopia	15.0	17	—	(40)	—	—	0.2	13,022	—	—
Saudi Arabia	6.0	2	—	(40)	—	—	0.1 –	365	—	—
India	411.0	101	200	34 (43)	.09	26	0.5	21,297	0.31	(67)
Philippines	19.5	66	375	32 (88)	—	8	0.6	14,848	0.20	(69)
China	463.0	48	110[c]	29 (23)	.03	3	0.5	246,584	0.24	70–75
Indonesia	76.4	40	200 –	22 (35)	—	21	0.4	16,231	0.18	(69)
Rest of Asia	—	—	200 –	—	—	—	[1.0]	—	—	—
Rest of Africa	—	—	200 –	—	—	—	—	—	—	—
Rest of America	—	—	350	—	—	—	—	—	—	—

[a] Includes Syria and Lebanon. [b] Includes Tunisia. [c] Includes Korea. [d] Figures in parentheses are United Nations estimates for 1946 or 1948. [e] Figures in parentheses are for agriculture only. [f] Figure in brackets for colored population.

Sources: See under table 1 for sources of cols. 2–5 and 7–8. Col. 6 is from Clark, *Review of Economic Progress*, 1, No. 4, 2, 1949. Col. 8 is taken in part from Guyol, *op. cit.* Col. 9 is from Usher, *op. cit.*, 40–43; it represents major energy reserves converted into terms of tons of bituminous coal. Col. 10 is from FAO, *State of Food and Agriculture, 1948*, 51, 72, and *Mission For Greece*, 155. Col. 11 is from United Nations, *Economic Survey of Asia and the Far East, 1948*, 110, and *Economic Survey of Latin America, 1948*, 87, and Hilgerdt, *op. cit.*, 26–27.

TABLE 3

CULTURAL AND DEVELOPMENTAL INDICATORS, BY COUNTRY

Country	Annual freight carried in ton miles		Motor vehicles (per 1,000 population)	Telephones (per 1,000 population)	Newsprint consumed per capita (kgs.)	Per cent of population age 10 and over illiterate	Daily per capita food supply			Physicians per 1,000 population	T.B. death rates per 100,000 population
	Per capita	Per capita per 1,000 sq. miles					All foods (calories)	Animal proteins (ounces)	Fats (ounces)		
(1)	(2a)	(2b)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
United States	2,977	37.2	250	148	31.8	Below 5	3,098	1.8	4.3	1.37	47
United Kingdom	424	19.1	53	59	26.1	Below 5	3,095	1.6	4.3	1.13	62
Argentina	671	29.2	21	27	7.9	17	2,777	2.2	3.3	1.05	103
Union of So. Africa	777	25.9	30	15	3.7	60	2,354	1.2	1.8	.41	Low
Chile	324	16.2	20	13	3.7	24	2,322	0.8	1.5	.63	264
U.S.S.R.	1,134	9.6	5	3	—	19	2,827	—	—	.76	160
Cuba	119	1.7	11	11	4.8	35	2,626	0.8	1.7	.63	76
Yugoslavia	43	0.6	1	3	0.8	45	3,013	0.7	2.1	.31	234
Poland	432	4.8	1	8	1.5	27	2,710	0.8	2.2	.32	195
Japan	138	1.3	3	16	5.5	Below 10	2,230	0.4	0.9	.87	207
Venezuela	—	—	10	5	2.0	63	—	—	—	.41	233
Egypt	69	7.7	2	3	0.8	86	2,469	0.4	1.5	.21	52
Palestine	77	2.6	10	12	—	69	—	—	—	1.38	56
Costa Rica	43	2.0	6	5	—	35	2,014	—	—	.25	172
Colombia	12	2.4	4	4	—	44	2,004	0.7	1.5	.29	Low
Peru	45	11.3	3	3	1.1	90	1,835	0.5	1.4	.19	High
Panama	26	1.5	23	11	—	47	—	—	—	.21	119
Ceylon	—	—	5	0.3	—	60	2,059	0.3	1.6	.15	62
Mexico	182	9.6	5	7	2.4	62	1,855	0.7	1.5	.51	56
Uruguay	514	19.8	31	16	7.6	30	2,426	1.0	3.3	.71	101
Dom. Republic	1	0.1	2	2	0.3	71	2,130	—	—	.20	Medium
Haiti	—	—	0.8	0.8	0.1—	90	—	—	—	.09	High
Nicaragua	10	2.5	0.7	1.5	—	57	—	—	—	.28	Medium
Guatemala	13	0.8	1	0.7	—	72	—	—	—	.11	Medium
Bolivia	—	—	0.6	0.9	0.4	92	—	—	—	.15	Medium
Honduras	19	1.1	1	3	0.3	68	2,079	—	—	.11	Low
El Salvador	9	0.3	2	2	—	73	1,944	—	—	.16	High
Brazil	94	15.7	4	5	1.3	62	2,173	1.1	1.8	.31	250
Ecuador	18	2.6	1	3	1.1	80	—	—	—	.24	High
Paraguay	23	5.8	2	3	0.4	65	2,813	—	—	.28	102
India	60	2.3	0.3	0.2	0.1	91	1,976	0.3	1.0	.12	283
Philippines	—	—	3	1.9	0.9	51	1,855	0.7	1.2	.26	298
China	17	5.7	0.2	0.5	0.2	85	2,234	0.2	1.4	.04	400–500
Indonesia	9	0.4	1	0.6	—	92	—	—	—	.02	High

Source: See under table 1 for sources of Columns 2a, 3–4, and 6–11. Column 5 is from the United Nations, *Statistical Yearbook*, 1948 (the figures are the higher of the 1935–39 and 1948 averages). Column 2b is obtained by dividing Column 2a by Column 7 from table 2.

TABLE 4

Economic and Cultural Indicators, by Region

Sources: Lines 1–3 are based on United Nations publications. Lines 4 and 5 are from United Nations, *Mission for Greece*, 155 (orchards and vineyards excluded). Lines 6–7 are from FAO, *State of Food and Agriculture*, 1948, 28. Lines 8 and 13 are taken or computed from FAO, *State of Food and Agriculture, 1949*, 134, 140. Lines 9 and 12 from United Nations, *European Steel Trends*, 132–136 (data for 1937 and 1939, whichever is higher) and 41. Line 10 from Guyol, *op. cit.*, 90 ff. Line 11 from Usher, *op. cit.*, 40–43.

Item	Region									
	North America	Oceania	Europe excl. U.S.S.R.	U.S.S.R.	Latin America	Africa	Eastern Asia	South Central Asia	Near East	World
1. Population growth, 1920–1947 (per cent)	36.5	33.3	17.7[a]	23.3[b]	62.8	41.5	24.8	37.0	29.8	31.1
2. Population in millions	157	12	384	195	153	191	738	426	74	2,330
3. Population per square km.	8.0	1.4	71.2	9.2	7.4	6.3	45.0	98.0	17	7.6
4. Acres crop land per capita	3.95	4.03	0.88	[2.00]	1.48	—	0.52	0.84	1.01	1.04
5. Acres crop land per head farm population	17.10	11.27	2.64	—	3.95	—	0.74	1.16	1.31	1.90
6. Productive forested area per capita (hectares)	3.0	4.2	0.3	3.2	4.7	2.0	0.3	—	0.2	1.1
7. Accessible productive forested area per capita (hectares)	1.96	2.2	0.3	1.6	2.2	0.95	0.15	—	0.07	0.6
8. % of world tractors ÷ % of world crop land	3.568	1.188	1.261	0.05	0.206	0.056	0.009	—	0.036	1.0
9. Steel consumption per capita (kilos)	371[c]	—	139	110	20	11	12	—	10	63
10. Energy consumed per capita (K.W. hrs.)	10.074	3,543	3,117	1,873	741	686	286			1,676
11. Energy resources (in tons of bituminous coal per sq.km.)	155,503	17,783	147,382	62,034	9,592	25,560	142,562	21,001	2,721	65,503
12. Known *ane* probable iron ore reserves (million tons)[d]	58,000	600	8,000	100,000	12,500	1,400	12,000			192,500
13. Textile consumption per capita (kgs.)	18.3	7.7	6.3	3.7	3.7	1.5	2.3			3.9

[a] Non-eastern Europe only.

[b] Eastern Europe and Asiatic U.S.S.R.

[c] United States only.

[d] Central America and Mexico are included with North America; Latin America includes only South America; Oceania includes only Australia. World *known* reserves total 24,050 million tons.

FARMERS IN A HUNGRY WORLD

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(Read April 20, 1950, in the Symposium on Problems of Development of Densely Settled Areas)

WE CAN, I am sure, for the purpose of this discussion, agree that (1) in most of the densely populated agrarian areas of the world, food supplies are on the average much below the level required for health and vigor; (2) this condition has prevailed for a long time; (3) it was worsened in many areas by the war; (4) there has been some recovery in production since the war in these areas; (5) in other countries (traditional exporters, notably the U.S.A.) food supplies are tending to outrun effective demand, both domestic and foreign; (6) no programs—either national or international—have been launched which will contribute very significantly to eliminating hunger and malnutrition in underdeveloped areas in the years immediately ahead.

Further, we can accept the proposition that there is a vast physical potential for increased food production in the underdeveloped areas themselves, in the countries with well developed agriculture, and in areas which are not now being used for crop production. And this takes no account of possibilities of synthetic foods from wood, from algae, etc.

If we agree that food supplies are inadequate in many underdeveloped areas but that food production can be increased greatly, both within these areas and in other areas as well, we can proceed to examine some of the economic, social, and political steps that must be taken in order for the farmers of the world to produce enough food for all, and for the food, after it is produced, to become available to the hungry people who need it.

I shall pass over the consideration of synthetic foods with the observation that their production requires the mobilization of scientists, technologists, and capital which now are primarily available only in the advanced countries where food supplies already are reasonably adequate, that production costs would have to be low enough to enable them to compete with "natural" foods. The synthetic foods would become available to the people of the underdeveloped areas only if those people were able to buy them or if the requisite science, technology, and capital were transferred to those areas.

Moving people to new lands is frequently proposed as a means of increasing the world's food production. There are indeed large areas of land that are not now under cultivation which could be made productive. Various authorities have placed the estimates of this area at something like one and a quarter billion acres of land (principally in the tropics and in the northern part of the North Temperate Zone).[1]

Large-scale international migration would be required, and the political aspects of present-day emigration and immigration resemble only remotely those which were present in the settlement of the Western Hemisphere in the eighteenth and nineteenth and early twentieth centuries. Huge capital outlays would be necessary, and much of the capital would have to come from foreign or international sources. Undesirable plant growth would need to be removed. Irrigation and drainage systems would have to be built. Disease—human, animal, plant—would have to be conquered. Crops, livestock, and farming practices, adapted to new soil and climatic conditions, would have to be developed. The settlers would have to have many of the traits of those who conquered the West here in the United States.

What are the possibilities of the people of the underdeveloped countries importing more food from those countries which now have supplies for export? The United States is the outstanding example, in the world today, of a country, with a highly-developed commercialized agriculture. With the exception of sugar and other sub-tropical and tropical products, the five and a half million farms of the United States produce enough food to afford the population of one hundred and

[1] Salter, Robert M., World Soil and Fertilizer Resources in Relation to Food Needs, Freedom From Want, a symposium for the American Association for the Advancement of Science, *Chronica Botanica* 11 (4), 1948.

fifty million people a per capita food supply that, with respect to both quantity and quality, is among the best in the world; and in addition, large quantities of both food and non-food products are available for export. Supplies are outrunning effective demand, in spite of the very high level of domestic employment and consumer income, and in spite of the large sums of money—grants as well as loans—the United States has made available to other countries in recent years for food purchases from the United States. Supplies have been mounting, and again the agricultural surplus has become a political as well as economic problem. But, even if these surpluses could be distributed to the areas of greatest deficit there would still be need for great increases in food production to meet nutritional needs there.

Traditionally most of the agricultural exports from the United States have gone, not to the underdeveloped countries, but to the highly-industrialized food-deficit countries of Western Europe. Now, those countries are unable to produce for export enough goods and services to pay for their traditional imports of food and raw materials. Each of those countries is now struggling to restore its balance of trade and balance of international payments. They are endeavoring to increase domestic food production in order to cut down their imports from the United States and other dollar areas, and at the same time some are endeavoring to develop new sources of supply in their dependent territories and in countries outside the dollar area where their imports are more welcome than they are in the United States.

It seems unlikely that this situation will be remedied in the near future. Thus much of the food which in recent years has been exported from the United States and other food-exporting countries to the traditional importers will be potentially available to other countries—including the densely populated agrarian areas, unless production in the exporting countries is drastically reduced or reoriented.

But these densely populated countries face the same problem as the traditional food-importing countries. What can they export, and how much, in order to obtain foreign exchange with which to pay for food imports? Their industrial production is low and, at best, will continue so for a good many years. Hence their export possibilities are mainly food and other agricultural products, and raw materials for industry.

There is some opportunity for expansion of agricultural exports to pay for food imports (e.g., copra from South-East Asia and jute from Pakistan). But it seems probable that in most densely populated agrarian areas, expansion of food production for indigenous consumption would be more economical as well as more socially desirable than reliance on large-scale expansion of production for export as a source of foreign exchange for food purchases. Food production in these areas can be expanded by improving the yield per unit of land already under cultivation and by increasing the area under cultivation. Much land not now in cultivation is capable of producing food—vegetable or animal or both. This is well illustrated in India, where authorities agree that twenty to twenty-five million acres of waste land could be brought into cultivation economically. In addition, not less than ten million acres which were cultivated at one time but which have gone out of cultivation because of infestation with deep-rooted weeds, are now being reclaimed by the Indian Government.[2]

In most cases, rather heavy investment and a considerable period of time are required to bring these areas into use. Expensive equipment is needed. Local people may not have the knowledge and skills (know-how) to plan and execute the work. An individual cultivator can do little by himself, and cooperative groups often are not able to mobilize the necessary resources. Private investors may not be interested because of the long period for which investment is needed and the unpredictable risks involved. Hence government aid is usually necessary, whether it be for a single large project such as the multipurpose development of a river valley or a series of smaller projects where the main work may be, say, sinking irrigation wells or the constructing of drainage systems. Even in the United States, many irrigation systems have been constructed by the government, especially where heavy construction and large amounts of capital were involved.

In many underdeveloped countries the governments are poorly organized. They have very little capital and the public servants (officials) do not have the know-how required to plan and carry through large land development-schemes. Government capital, in the last analysis, can come only from some form of taxation and if people have only a little wealth and only small

[2] Sethi, D. R., Agricultural development commissioner to the Government of India, land reclamation. Prepared for United Nations Scientific Conference on the Conservation and Utilization of Resources, Lake Success, New York, 1949.

incomes, taxes cannot raise a great deal of money. The government can borrow money, either from its own people (creating internal debt) or from foreign citizens, foreign governments, or international organizations, as the International Bank for Reconstruction and Development (creating external debt).

Citizens of a poor country cannot save much, hence have little to lend to their government, even if they want to. Consequently foreign or international borrowing becomes necessary. Citizens of foreign countries hesitate to lend to many governments because they feel there is not a good prospect of the principal and interest being paid on schedule; war might come or the present government might be overthrown and the succeeding government repudiate the debt. (Defaults on bonds of foreign governments bought in the United States in the 20's afford a striking example of the risk involved.) Many of the same problems arise when one government is considering a loan to another government. The International Bank for Reconstruction and Development has very meager resources, and on account of the way it must obtain its capital (the sale of bonds to private persons or institutions), feels it must give great weight to credit-worthiness of loans it makes.

If a loan is to be repaid from its own earnings, many loans for agricultural development must be quite long-term (e.g., 50 years) with beginning of interest and amortization payments delayed for several years after the loan is made, that is, until the project for which the loan is made can become productive.

The obvious remedy and the one most often advanced is: more liberal lending policies by national governments and by international agencies. This of course is necessary but not sufficient. In order that there may be more liberal lending policies, the borrowing governments must be secure, honest, and able to repay. To attract capital, plans must be realistically developed, they must show income potentials large enough to provide repayment, and prospective lenders must be satisfied that the program of development will be carried through efficiently and economically. Peace is, of course, all-important—if a country fears aggression or a government fears internal disorder it will spend much of its income on armament. In any case, a loan must be used for the purpose for which it is granted. The borrowing government must have a fiscal policy and a method of fiscal management that will insure funds being available to meet payments of interest and amortization as they come due.

But, making funds for development available and insuring their proper management is not sufficient. Dams must be built, land cleared and levelled, irrigation and drainage ditches dug, roads and houses built, farms laid out. Settlers must be induced to come. They must have equipment. They must know what crops and livestock are best adapted to their farms. They must know how to farm their land productively, and must have money or provisions to live on until their crops are harvested. And they must be able to sell their produce for enough to pay their running expenses and make a beginning on repaying the costs of establishing their farms. Too often costs are higher than anticipated, farms are too small to allow most efficient use of the cultivator's labor and other resources, and markets for produce are not as good as it was hoped they would be.

Of course all of these requirements (at the government level, at the "project" level, and at the "producer" level) have been met in many areas where farming is now well established and producers reasonably prosperous. But this mere enumeration of them serves to indicate why progress in new land development has been so slow in many areas where the potentialities are great. And it outlines the task that confronts any agency—public or private—which undertakes it. Development necessarily comes step by step. And the steps often will not be taken in the order in which they were taken on the lands which have already been developed.

The obstacles to progress in increasing production on land now under cultivation would seem to be more easily overcome, but many have existed for centuries and are, in fact, a part of the culture and environment of the people. Found alone or in combination, they are responsible for low yields, in spite of the great amount of labor applied to each acre; often the same soil-depleting crop is produced year after year; erosion has taken its toll and the fertile topsoil disappeared long ago. Little or no natural or commercial fertilizer is used. Pesticides to combat insects and fungi, and vaccines for the prevention or cure of livestock diseases are practically unknown. Pastures are unimproved and overgrazed. Drainage is needed in many areas. Where water for irrigation is used, the supply is often undependable, and may be used wastefully. Only poor seed of unimproved varieties is available to the

farmer for most of his crops. Improved breeding of livestock for increased production is needed. Feed for the livestock, especially grain, is usually so limited that the productivity of the livestock is far below the physical potential. Food for the people is so scarce that most of the cereals and other grains are used directly as food. Farm implements are primitive—often the cultivator has only a hoe and other hand tools; and the largest power-unit in the community is a single bullock or at best a pair of bullocks. Forms of land tenure in many areas are still substantially the same as they were in ancient times.

The application of science and technology to farming, along with the provision of capital for modern equipment, have been the principal factors in the remarkable increases in productivity in the United States and other so-called advanced countries in the last half-century. But up to the present, in the areas we are discussing, this has been done, if at all, mainly in relation to export crops on large plantations and estates. The great majority of the peasant cultivators are still using the methods and practices of their forefathers which have been developed over the centuries. These methods and practices cannot be discarded easily, but they can be improved greatly by some relatively simple measures. Improved hand tools and animal-drawn implements, for example, will bring a greater immediate increase in the productivity of many regions than would the introduction of the complicated machines and practices now being used by commercial agriculturists in the advanced countries.

If farmers are to make improvements, they must have knowledge they do not now possess. They must have incentives for improving their lot, they must have a social structure through which they can carry on the necessary activities, and they must have financial means (capital) now beyond their reach. In the last analysis, this may involve changes—in some cases major changes—in the economic, social, and political structure of an entire nation.

A large portion of the rural people in these areas are illiterate, and most of the remainder have only a rudimentary education. They tend to accept traditional practices without question, do not search eagerly for innovations, and are not ready to experiment. Knowledge concerning improved farming, nutrition, health (and everything else) must come to them largely by word of mouth and by demonstrations which they can see and understand. The people are likely to be distrustful of strangers (especially those from foreign lands) who come to tell them what to do and how to do it. To be successful, the teacher must know and understand the habits, customs, traditions, and taboos of the people he is trying to teach, and must fit his words and his actions to background.

And even when the people understand, the incentive to act may be lacking. They have lived for generations at a low level of subsistence; they are likely to feel that they would reap no personal reward from increased productivity in farming or any other activity (it would be taken by the tax collector or the landlord); malnutrition and disease may have lowered their energy to the point where they feel that any extra effort is not worth while.

And even if one has the requisite knowledge and incentive to increase his productivity, he will usually need money (capital) in order to inaugurate improvements. Fertilizers, machines, insecticides, improved seeds must be paid for. If he sells part of the food he produces to get the money to pay for them, he may not have enough food left to support his family until the next harvest. Often interest rates and other charges are high and the only source of credit is the local merchant or money-lender.

In most densely populated areas the farms are generally so small that, even with all the improvements we have enumerated, great numbers of farmers must have additional land in order to increase their productivity enough to enable them reasonable progress in improving their levels of living. Long-term loans at reasonable rates of interest are a requisite for land purchase. Enlargement of farms, by either purchase or rental, means fewer farms.[3]

[3] In colonial areas, the fundamental problems are not different from those in self-governing areas. This is now recognized by many colonial administrators and officials. For example, the delegates (all of whom were officials of the United Kingdom and its African colonies concerned with agricultural development) to a British Land Utilization Conference in Nigeria in 1949, emphasized that development is dependent on cooperation of the mass of the people, and that to gain this cooperation it is "necessary to provide them with suitable conditions and incentives . . . including (*a*) secure tenure of an adequate holding, (*b*) the benefits of access to development capital, (*c*) the possibility of obtaining agricultural credit, (*d*) the removal of natural handicaps such as water shortage and tsetse fly; (*e*) the opportunity to increase productivity by the adoption of improved methods, (*f*) adequate marketing facilities, (*g*) improved social services and social standing." (See Final Report, British African Land Utilization Conference, Jos, Nigeria, November 7–9, 1949.)

The Republic of Haiti may be cited as an example of a densely populated agrarian area where most of the problems cited above exist today. A United Nations Mission on Technical Assistance appraised the situation there in 1948 and made a number of specific recommendations for improvement. The Republic has a population density of about 300 to the square mile; the per capita annual income is about $25. Probably 85 per cent of the population is dependent on agriculture. Eighty per cent of the area is mountainous. Farms are very small, with the exception of a few plantations of bananas, sugar cane, and sisal. Coffee is the peasant's principal cash crop. Typical farm implements are the machete and hoe. Wheeled vehicles are not used much outside the cities. The diet of most of the people is close to the starvation level; clothing is inadequate, houses are built of poles and mud, and workmen lack stamina. To most, credit is available only from merchants who buy produce and sell supplies to the peasants, making successive loans against forthcoming crops. Governmental efforts to improve the situation have been hampered by discontinuity of policies and procedures, diffusion of effort, lack of coordination of governmental services, and conflicts of interest between the producing peasants and those interested in exports.

In making its recommendations the Mission emphasized that agricultural development cannot go very far unless it is accompanied by industrial development and improvements in education, public health, credit, and public finance.[4]

The village of Bhuvel in Burada State in India affords another striking example.[5] The population of the village in 1947 was 1,070. It had increased 40 per cent in 25 years. The area of cultivated land has not increased. Although the area under irrigation has been expanded it still is only one-fourth of the total. There are 400 children under 14 years of age. More than 80 per cent of the families are directly dependent on agriculture. Average food consumption was in 1947 only 2,360 calories per caput per day. The diet is deficient particularly in fats, protein, and calcium. For a majority of the people intake of milk, vegetables, and fruit is very low. Nearly half the people are underweight (when compared to the Indian standard of height and weight according to age prepared by the New India Assurance Company) and only about one-fourth are free from disease.

The cultivated area of the village is less than 900 acres, divided among 133 cultivators. One-half of this land is cultivated by tenants. The rent most commonly paid is half the crop. Further, 49 per cent of those dependent on agriculture are landless farm laborers whose wages approximate one rupee (21 cents) per day. The village has neither a post office nor telegraph office. But on the other hand, it has an outstandingly successful cooperative society, and 60 per cent of the population above school age can read and write, as compared to 15 per cent for India as a whole.

A team of native investigators—man and wife—who spent a year in the village concluded that measures to improve the condition of the villagers must include: irrigation of more land to increase its productivity; new avenues of employment; changes in land ownership, tenancy, and taxation patterns to "reduce the burden on the cultivator and to ensure him the full fruit of his labor"; increase in productivity of both crops and livestock; better health and sanitary measures; better schools with agriculture and handicraft in the curriculum; and reform of the village administration to make it fully representative of the villagers and to enable it to do its work efficiently and promptly.

In closing their report the authors observe: "We have found that the people do have a desire for improving their village, economically and socially. What they lack is the proper guidance and the necessary assistance. . . . A little encouragement or a word of hope mixed with practical advice succeeds in harnessing the human and material resources in the village and in persuading the villagers to take a step forward in one direction or the other."

Greece, once a leader among nations, has remained primarily agricultural, while population density has increased. There is about one and one-third acres of arable land per head of farm population, compared to seventeen acres in North America. Yields of grain per acre average only about 13.5 bushels, not more than half that in most other countries of Europe. Approximately 50 per cent of the population is dependent on agriculture, as compared to about 25 per cent in France and Denmark. Before the war, food available for consumption (including large quan-

[4] Report of the United Nations Mission of Technical Assistance to the Republic of Haiti, Lake Success, New York, July 1949.

[5] Shah, Vimal, and Sarla Shah, *Bhuvel, Socio-economic survey of a village*, Bombay, Vora & Company, Publishers, July 1949.

tities of imported grain) provided only 2,500 calories per person per day. In addition, the composition of the diet was poor. The consumption of meat and dairy products was quite low.

In 1946 an FAO Mission studied agriculture, fisheries, and related industries there and made recommendations for their rehabilitation and long-range improvement.[6] The Mission recommended a broad development of water resources (drainage, flood control irrigation, and hydroelectric projects) to provide for great expansion and modernization not only of agriculture but of industry. Many technical measures to improve agriculture were suggested but the Mission came to the conclusion that, even with full development of irrigation and of intensive agriculture, Greece could not profitably support her present proportion of farm people. It advocated improvements in education, increased technical and financial facilities for the cooperative movement, reforms in the tax system. The need for extensive industrial development, and the necessity for external loans to carry through the agricultural and industrial developments were stressed. Now that guerilla warfare has ceased, and both investment funds and technical assistance continue to be available, it seems that relatively rapid strides can be expected, provided the Greek people establish a stable and progressive government.

These three areas, as well as many other densely populated agrarian areas, are characterized by low productivity and low income per person, small agricultural holdings, high birth rates, high mortality and short life.

In addition to what they can do to help themselves, producers must have help from their government or some other source to improve their health and education, to acquire new skills, to learn of improved methods and practices and how to apply them. And they must have sources of credit at reasonable interest rates and on terms suited to their needs.

Then as improvement progresses, and more food and other agricultural commodities are produced, the farmers and their families will have more and better food, and more produce will be available for sale. More and better food will help to lower the death rate, the people will become more vigorous, and the net productivity of the entire population will increase. Increasing productivity will most likely call for larger farms; reduced death rates contribute to increases of the farm population. Unless there is concurrent industrial expansion the result might simply be unemployment or underemployment. The appearance of more food and other agricultural products for sale to non-farm consumers would also call for expansion of non-farm employment.

And as the people acquired more education, as their standards of living as well as levels of living rose, and as the country became more urbanized, it is to be expected that the birth rate would fall.

I have not mentioned land reform, overhauling of tax structures, expansion and strengthening of rural cooperative organizations, and many other lines of action which would help to increase food supplies and enhance the welfare of rural people in these areas. But it is obvious that a combined attack on many fronts is needed if population pressure is not to increase, social structures deteriorate, and economic productivity decline. Some who have pondered this dilemma have concluded that the only hope is dictatorship and totalitarian governments, that at best democratic processes are too slow and cumbersome, and that the people are "not ready for democracy." But I do not agree with them.

As a matter of fact, the people in many of these areas are only now escaping from despotism and feudalism like that which we associate with ancient and mediaeval times. And more and more of them are demanding that they be permitted to participate in planning the programs of economic, social, and political improvement in the locality, the province, and the nation. At the same time there is a growing awareness on the part of the people of the so-called advanced countries that their prospects for peace and prosperity will be influenced to a considerable extent by the course of events in the so-called underdeveloped countries.

Along with this growing awareness has come a willingness and desire to extend aid to these people and governments in their efforts to raise their levels of living. This is exemplified by the establishment of the Economic and Social Council of the United Nations, the Food and Agriculture Organization, the World Health Organization, and the United Nations Educational, Scientific and Cultural Organization. The enthusiastic response to President Truman's Point Four Program in both the highly developed and underdeveloped countries throughout the world is indicative of this willingness and desire.

[6] Report of the FAO Mission for Greece, Food and Agriculture Organization of the United Nations, Washington, March 1947.

The situation is by no means hopeless. The problems are great, but not insoluble. The process of sharing the technology and economic intelligence of the advanced countries with the people of the less advanced countries can be greatly accelerated. Arrangements can be made for the underdeveloped countries to have access to a little more of the investment capital of the advanced countries. The peoples and the governments of the underdeveloped countries will have to assume the primary responsibility of transforming scientific discoveries and technological advances into practices compatible with their social and economic patterns, and of using their own capital as well as that from other countries economically and effectively.

Technical assistance and advice, which necessarily come largely through technically competent people from the developed countries, can be of great help in both respects. On the food and agriculture front, this assistance includes not only the services of scientists and technologists who know how to improve plants and animals, and engineers who know how to design and construct irrigation and drainage works. Also it includes economists who can advise on how to reorganize and reorient agricultural production, how to channel national savings into productive enterprises and how to develop or improve credit and marketing systems; extension or advisory specialists to help carry knowledge to rural people, and in turn to help governments keep their programs oriented to the special requirements of rural communities; and even statisticians to help devise ways and means of finding and summarizing the facts concerning changes in production, consumption, and trade, and the economic and social status of the rural people.

A very important field for advice and assistance is improving the organization and efficiency of government services—national, provincial, and local—so that the programs and policies of the nation and its parts can be harmonized and unified and the respective functions of the national government and provincial and local governments integrated and harmonized.

And even more important is advice and assistance in obtaining "citizen participation" in formulating and carrying out programs, determining the part to be played by government and the part to be played by the people, acting individually or in groups; and the order in which the different phases of the programs should be undertaken. Government officials may be most sincere in their desire to bring to their country the knowledge and know-how of the people of other countries, but still not know how or where to begin. For example, a high official in one of the smaller underdeveloped countries recently said to a representative of our Organization, when the subject of technical assistance was being discussed, that the first need of his government was for advice and assistance in determining what kinds of technical assistance could be used effectively by his government in developing the agriculture of the country and improving the welfare of its rural people.

The method by which a government can obtain technical assistance from external sources is similar to the method of obtaining investment funds. It can be obtained only through negotiation with citizens or non-governmental institutions in a foreign country, negotiation with a foreign government, or negotiation with an international agency. Private citizens and non-governmental institutions in advanced countries have made, and can continue to make, significant contributions. Government-to-government arrangements for assistance in improving agriculture and increasing food supplies (and in other fields as well) have been carried out effectively in the past and can be in the future. The United Nations and specialized agencies have up to the present been able to supply only a limited amount of assistance in the field of food and agriculture (or any other field). This has been due mainly to their severely limited financial resources and urgent requests by member governments for other services.

But, as technical assistance in the development of underdeveloped areas expands, progress will be accelerated if governments assign an increasingly important role to these agencies. These international agencies can draw on the resources, experiences and skills of all of their members in cooperative efforts for the solution of international economic, social, cultural and humanitarian problems, in raising levels of nutrition, in bettering the condition of rural people, and generally contributing toward an expanding world economy.[7] The underdeveloped countries as well as the highly developed countries take part in shaping the programs of the international agencies. The representatives of the international agencies frequently will be welcomed as advisers and assist-

[7] See particularly Articles 1 and 55 of the Charter of the United Nations, and the Preamble to the Constitution of the Food and Agriculture Organization.

ants where representatives of a single foreign government might not be. Many of the countries which can reap great benefits from external assistance—both technical and financial—were dependent territories only a few years ago, and they fear that if they accept aid now from a single foreign power, it may try to exert an undue influence on their internal political and economic affairs. Virtually every underdeveloped country has made progress in some field and has one or more technicians who, because of their special experience, may be more useful to another underdeveloped country than persons with equal skill and experience, but from a different environment.

President Truman proclaimed in January 1949 that the expanded program of technical assistance should be a cooperative enterprise in which all nations work together through the United Nations and its specialized agencies wherever practicable. Since that time these agencies have made comprehensive and carefully coordinated plans for a rapid expansion just as soon as additional funds become available. Obviously, a large proportion of the assistance would go to densely populated agrarian areas.

At the General Assembly of the United Nations in November 1949, nineteen nations declared their intention to contribute—usually personnel as well as funds—to the program through the United Nations and its agencies. The contributions of the various nations and the conditions relating thereto have not yet been announced. This will be the real test. It will show whether governments are ready to cooperate in a world-wide program of dissemination of useful knowledge and assistance in applying this knowledge for the benefit of mankind. With regard to food supply, resources and knowledge to produce enough for all are available. In agriculture, as in other fields, the problem is that of spreading knowledge and improving economic, social, and political institutions. If the peoples and nations in the positions of leadership in the world today would devote as much of their resources and energy to this as they are now devoting to atom and hydrogen bombs and other means and methods of destruction, the last half of the twentieth century would go down in history as an era of advancement much greater than any period of the past.

CHLORELLA AS A SOURCE OF FOOD

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THE problem of food supply is as old as mankind itself. With the apparent shrinking of the world, particularly since the last war, and with our growing awareness of the ever-increasing world population demanding a rising standard of living, the grimness and formidable proportions of this problem are causing concern to even this, the most favored of nations. Of the tremendous amount which has been written and spoken on this problem it would seem that there are three principles on which a fair degree of agreement can be reached:

1) The food problem is above all a practical one, practical in the sense that contributions towards its solution must ultimately demonstrate actual usefulness within the medium of present-day society. By contrast, the oft-repeated schemes of the artificial synthesis of food stuffs, independent of the plant or animal, must for the immediate purpose be regarded as fanciful and unrealistic.

2) The production of food, as practised throughout the world today, is an extraordinarily complex process, presenting almost innumerable economic, politico-social, practical, and scientific problems. Hence it is the meeting ground for many disciplines, speaking different languages with all too little common understanding. Of the many facets to the problem no single one can be permanently regarded as the dominant one.

3) In consequence of this great complexity, involving climatic, edaphic, economic, and social variables, it would be highly hazardous to rely upon some single revolutionary step or procedure as the key to the solution. There has been an abundance of visionary schemes. Hope of success seems rather to lie in the direction of concerted evolutionary effort along a wide front, through the critical cooperation of many disciplines.

This is no time to indulge in the spirals of quixotic dreams. True, vision is necessary, but the vision must be a disciplined and practicable one.

It is always very hazardous to over-simplify the problem of food production. Yet from one point of view food production is essentially dependent upon the photosynthetic capacity of an area of land. In the past increased food production has been attained primarily through the extension of the land areas which have been put under cultivation. To a considerable extent this has been possible through the use of machinery and scientific application of fertilizers, the development of adapted genetic strains and through the control of diseases and pests. Fortunately we have been given hope of developments in all of these directions for increasing world food production. It is, however, important to bear in mind that in all of these possible extensions the fundamental process, that of trapping the energy of the sun through photosynthesis remains the principal synthetic force.

Let us look at the matter for the moment from the point of view of the utilization of solar energy by the plant in the simplest terms. As a matter of practical experience, the plant under field conditions converts only a very small percentage of the solar energy falling on it into organic material. Of the 7,300,000,000 kilocalories of the sun's radiation falling on an acre of land per year only about 0.1 to 0.5 per cent is fixed as organic material in the temperate zone. And when we speak of organic material synthesized by the plant it is well to bear in mind that only a portion of this, usually not more than one-half, is in the form of what is ordinarily considered a crop of food stuff.

The factors which make for this astonishingly small return are varied and some of them are rather complex. But we may examine for the present purpose some of the more obvious ones. In the temperate zone the period during which plants can grow is only about four months. During much of this time the plants are small

and can utilize but a small percentage of the area of land, thus making use of only a fraction of the energy falling thereon. Actually, it has been found that during a period of four months, representing the growing period of a corn crop, a total conversion of about 1.5 per cent was attained counting the shelled corn, cobs, leaves, stalks, and roots. Of this total dry-weight about one-half is in the form of grain. Obviously, the tropical regions have a distinct advantage because of the long growing season, which accounts for the relatively high conversion factors in undertakings like the Hawaiian cane sugar plantations.

There is another important circumstance which makes for the low efficiency in the utilization of solar energy by the plant. About one-half of the total solar radiation is composed of heat rays and infrared radiation. These wavelengths are not effective in photosynthesis. Consequently, the plant is capable of utilizing for the synthetic process only one-half of the radiation incident on it.

Given a well-functioning machine, in this case the elaborately constructed leaf with its complex system of pigments for absorbing light energy, its series of enzymes for promoting the chemical reactions and disposing of the end products, it is essential that this machine should be provided with an adequate supply of raw materials, in order to obtain maximum production. The raw materials for photosynthesis are primarily carbon dioxide and water. Reduced to its very simplest terms, the water serves the process of photosynthesis largely as a source of hydrogen, which in turn is used to hydrogenate, or reduce, the carbon dioxide, the oxygen of the water being eliminated as a byproduct. The carbon dioxide, on the other hand, serves the process of photosynthesis as the raw material from which are formed the organic substances through this reduction process. The water and carbon dioxide economy of the plant are consequently of the greatest significance. Because of its more obvious nature much attention has been given to the water. But clearly one of the most significant factors in the production of organic matter is the concentration of carbon dioxide in the air, for it is from this source that all the material produced by the plant is derived. There is only 0.03 per cent carbon dioxide in the atmosphere and on this thin thread hangs our very existence. If the percentage of carbon dioxide is doubled, the rate of photosynthesis is also doubled, and it has long been known that the production of crops can be very materially increased through enrichment of the air with carbon dioxide. This, then is a positive means of increasing the effective use of the quantity of sunlight falling on a given area of land.

To some of us who have been looking at the problem of world food supply from a point of view and scientific background somewhat different from that of the food economist, of the agronomist, or of the soil expert, the question has repeatedly occurred whether it might not be worth while to make some preliminary examination of other approaches to the problem. One naturally wonders how an engineer would regard the problem. If he had charge of engines which converted only about one per cent of the fuel consumed by his prime mover, and it was demanded of him to produce more power, what would be the course of his approach to the problem? Would he not at least look into the question as to whether he could increase the efficiency of his generator system? Or would he simply construct more generators of the same low efficiency?

In probably no important endeavor is man so strongly bound to the past as he is in the matter of the production of his food. In provision for shelter, means of transportation and communication, protection against weather, and methods of waging war he has made truly fundamental advances. In comparison with these activities, agriculture is to an astonishing degree still bound to the past. Most of our crop plants were brought into cultivation by primitive man. He took the plants which were at hand in the wild. Through a long and exceedingly complex process these plants have been brought to give higher yields and food of better quality. The application of modern concepts of genetics to plant breeding has, it is estimated, on the whole increased yields by some 40 per cent. It seems doubtful whether improvements in this direction can be expected to improve yields so that they even approximate the estimated increases in demand for food. The question quite naturally arises whether we have sufficiently explored the synthesizing capacity of plants for the fundamental materials constituting our food stuffs, carbohydrates, proteins, and fats, throughout the tremendous diversity of form and function which characterizes the plant kingdom. The portions of the plants on which we now rely for our food sources—seeds, tubers, and other storage organs

—are, as a matter of fact, derived from an astonishingly small portion of the plant kingdom. They are for the most part higher land plants. Of these only a relatively small portion is suitable for human consumption, much of the organic material which is synthesized by the plant is cellulose and as such has little nutritive value.

A striking feature of the plants which man has used as a source of food is not only that a small portion of the plant is usable as food, but the very structure of the plant seems ill-adapted to his purposes. The primary manufactory of the plant is in the green leaves. It is here that the synthesizing processes occur which produce the food stuffs. From the leaves the organic materials migrate to other parts of the plant and are laid down in seeds and tubers as storage materials. The distance between the manufactory and the storage organ is often great. Much of the material which the leaves manufacture is used in the construction of the transportation system and another portion is used in the maintenance of this system. In brief, in the plants commonly used for food production a very considerable proportion of the material produced by photosynthesis is not directly available to man.

We are here concerned with the most effective utilization of the solar energy incident upon an area of land by the usual crop plants. The very nature of the development of these plants makes for relatively low utilization. The seeds are planted in the soil and a long time of growth is required before sufficient leaf surface has developed to form anything like a complete coverage of the land area to absorb the maximum quantity of light. For example, with wheat, oats, and barley during the first six weeks of growth only about one-quarter of the maximal leaf surface is developed. During the next two weeks an additional one-quarter is formed. In the ninth week alone the final half of the maximal leaf surface is developed. Thereafter, for only two or three weeks is the plant manufacturing organic material at its maximal capacity.[1]

Essentially, therefore, this usual system of utilizing solar energy constitutes what is industrially termed a batch process. The start is at zero efficiency and is slowly built up until maximal efficiency of the system is attained. This is used for a very short time, after which the process ceases, and must again be started anew. Although this course is largely determined by climatic factors, it raises the question as to whether some of the principles of a continuous process, which have been so eminently successful in many industrial operations, could not be applied to manufacture of organic material by plants.

The shortcomings of higher plants as photosynthetic machines for the production of consumable food are, therefore, fairly obvious. In contrast to these organisms, lower forms of plant life may present some advantages. For example, unicellular green algae are relatively highly efficient photosynthesizers. Each cell contains a large amount of the pigments essential to photosynthesis; the organic material formed in the process is stored within each cell. The growth of the plant takes place primarily through the division of each cell into 4, 8, or 16 new cells, each of which is capable of photosynthesis and of further division about every twelve hours under favorable conditions. Thus the photosynthetic machine consists of a huge number of minute cells, each about 3 to 8 microns in diameter, the population freely suspended in water. For the growth of the population or culture there are required only simple inorganic salts dissolved in water, carbon dioxide as the only source of carbon, light to carry forward the photosynthetic process and a temperature about 25° C. The organic material synthesized consists mainly of proteins, carbohydrates, and lipids.

Lower organisms of this nature, of which the unicellular alga, Chlorella, has been given the most attention have, moreover, another remarkable feature which may prove to be of significance for a source of food. They are remarkably flexible, in the sense that their composition can be altered at will. The composition of higher plants in regard to the relative amounts of carbohydrates, proteins and fats is fairly constant, because their very structure demands that a relatively large amount of the plant is composed of cellulose. Not so in the case of a plant such as Chlorella. For example, by careful control of the composition of the mineral nutrient solution, of the light intensity and the age of the culture, a wide variation in the relative amounts of the chemical constituents can be attained. Thus it has been possible to vary at will and in a thoroughly reproducible manner, the percentage of lipid material produced by Chlorella from about 5 per cent to 85 per cent.

Considerations of this nature have led to

[1] Walter, H. Der Assimilathaushalt unserer Kulturpflanzen unter feldmässigen Bedingungen, *Biol. Zentralb.* **67**: 89–94, 1948.

attempts to utilize photosynthetic microorganisms as sources of food. In this country efforts have been directed principally towards the use of the unicellular green alga, Chlorella, and in Germany during the war, certain diatoms were investigated. It can, of course, not be claimed that Chlorella is the best organism for the purpose in hand, although the comparative studies of Ketchum, Lillick, and Redfield[2] show that of five green algae, *Chlorella pyrenoidosa*, in yield of cells and in dry weight, was superior to the others. In view of the very large number of species which should be considered, this aspect of the problem is still wide open, and can hardly be discussed at this time.

The requisites for the growth of an aquatic organism such as Chlorella are essentially the same as those of any ordinary crop plant. In the case of Chlorella, however, some of these requisites can be more exactly controlled than is the case with plants growing in the field. The organism grows in water and this must, of course, be retained in a vessel or chamber of some sort. There are consequently only small losses of water. The essential mineral nutrients are salts of fixed nitrogen compounds, of potassium, phosphates, magnesium sulphate and the so-called trace elements. The source of carbon is carbon dioxide, and this gas is supplied in a mixture of 5 per cent with air. Air thus enriched with carbon dioxide greatly increases the rate of photosynthesis, though concentrations above 5 per cent are not advisable. The gas stream also provides a desirable element of turbulence in the culture. The driving force of the process is, of course, light, and the most effective use of sunlight constitutes one of the most important problems of the entire undertaking. Experience thus far obtained has emphasized the necessity of sterilizing the entire system, nutrient solutions and illumination chambers, to prevent contamination with other organisms. Very briefly stated, these are the requisites for the culture of this organism.

In order to explore the possibilities of mass growth of Chlorella on an industrial scale and the attendant engineering problems, a study was made by the Stanford Research Institute under financial support of the Research Corporation. It will be possible to mention here only some of the more significant conclusions of this study. Moreover, practical considerations bring into focus many purely scientific problems which must be solved before the important engineering features can be put upon a sound basis. The entire undertaking must, therefore, be considered as being still in the highly experimental stage.

For the utilization of Chlorella in mass culture one of the basic factors is the growth rate of the organism. When nutrient solution is inoculated with Chlorella cells, the population density increases only very slowly during about the first week; thereafter there is a very rapid increase in the number of cells per unit volume, which continues for about two weeks, after which the rate of increase in population diminishes. The causes underlying these variations in the growth of the population are rather complicated and are only imperfectly understood.

In any industrial process *time* is an all-important element. The product should be produced as rapidly as possible and the apparatus or farm in which it is produced should be used to its greatest capacity and highest efficiency. It seems obvious, therefore, that for a continuous process of culturing Chlorella the cells should be multiplying and growing as rapidly as possible and it is important to establish and maintain the most favorable conditions for the rapid growth of the culture. As a matter of experience, the development of a culture of Chlorella is a rather complex process, dependent upon a number of interacting factors. Moreover, the growth conditions selected depend a great deal upon the purpose for which the Chlorella culture is intended; one set of conditions will produce cells high in protein and relatively low in lipids, whereas another set of conditions will produce cells of high lipid content and of low protein. In the interest of simplification the production of high protein cells will be considered, because in any system designed for high lipid content the cells must first go through a stage of high protein content.

What is desired in order to make any system for growing Chlorella practicable is high yield; but not only high yield alone; there must be high yield in the shortest possible time and in consideration of the volume of water that must be handled. Yield in relation to time, means growth rate. Yield in relation to the volume of water to be handled, means population density, i.e., the weight of cells per unit volume of water. Now it is clear from the growth rate curves, that at low population densities the growth rate

[2] Ketchum, B. A., Lois Lillick, and A. C. Redfield. The growth and optimum yields of unicellular algae in mass culture, *Jour. Cell and Comp. Physiol.* **33**: 267–280, 1949.

is relatively high, but the total yield per volume of water is low. On the other hand, at high population densities the growth rate is low. Consequently, one of the most important features of the mass culture of Chlorella concerns the variation of growth rate and yield as a function of population density under constant conditions in a continuous process. As a matter of practical experience obtained thus far, it has been found that the population density should be maintained at about 0.36 gram dry weight of Chlorella cells per liter of nutrient solution to maintain maximum production under conditions of culture which appear to be optimum. At lower population densities light is not being used efficiently and there is an inordinate quantity of water to be handled; and at higher population densities there is a decided decrease in the growth rate.

This relationship between growth rate and population density may be of decisive importance for the practical utilization of Chlorella as a source of food material, for it affects many of the engineering and economic features. The underlying causes for the decrease of growth rate and yield at high population densities is still rather obscure and constitutes an important scientific problem of general interest. One clue has been found in the autotoxin produced by dense cultures of Chlorella. This inhibitor to growth, which has been termed "chlorellin," is apparently a metabolic product of Chlorella cells and accumulates in dense cultures. A feasible means to remove or destroy the autotoxin produced in Chlorella cultures, and thereby increase growth rates at high population densities, would be a fundamental contribution to the entire undertaking. This is true because higher growth rates at high population densities would materially affect the processing charges involved in the handling of the large volumes of water required for large scale mass cultures.

Time will permit only a brief outline of the mechanical means which have been devised to accomplish large scale culture. This is, of course, essentially an engineering problem. The underlying principle is the maintenance of optimum conditions for maximum growth and utilization of solar radiation in a continuous system. If supplied with the necessary mineral nutrients and if optimum growing conditions are maintained, growth will always take place at a maximum rate. Moreover, since the organism divides once in about every twelve hours, the increase can be continually harvested, leaving at all times the same number of cells in the system under a favorable environment for further maximum production. The number of cells which it is desirable to leave in the culture system is determined primarily by the intensity of light available.

The entire process may, therefore, be divided into two parts:

1) The culture system or farm.
2) The processing plant for the preparation of the aqueous medium and the harvesting of the cells.

The design of the culture system entails consideration of a large number of complex variables in order to attain the most efficient utilization of solar energy. Not the least of these considerations, if the system is to be practical, are matters of cost of capital investment. A great variety of architectures or shapes of culture chambers have been suggested. Among the more promising the following may be mentioned:

1) A flat horizontal surface.
2) Vertical cylinders.
3) Cylinders inclined normal to the sun's rays.
4) Horizontal cylinders.

Special studies by Professor Lindquist and Mr. C. R. McEwen of the comparative efficacy of these types of architecture have shown that the best utilization of solar energy may be attained by the inclined cylinder. Only slightly less effective is the horizontal cylinder, while the flat horizontal surface and vertical cylinder are both 30–40 per cent less efficient than the normal cylinder. Costs of construction and maintenance, however, at present seem to be unfavorable to the use of the cylinders of normal and vertical exposure. The final selection depends upon further cost and efficiency analysis.

What for convenience may be termed the processing plant is for the most part standard engineering practice. It involves the preparation of the nutrient solution, sterilization thereof and of the culture chambers; circulation and aeration of the medium, and finally harvesting i.e., the removal of the Chlorella cells from the nutrient solution, drying, and similar processes. Probably the outstanding feature of the processing phase in a large scale undertaking is that it involves the handling of enormous quantities of water, and this entails expensive equipment and power. This is of the general order of 2,500

pounds of water for each pound of dry Chlorella. When it is considered that for a plant of this sort to be at all efficient it should produce let us say from 50 to 500 tons per day, it may be realized what the order of magnitude of a Chlorella farm should be. Without being able here to go into the essential details, the studies which have been made thus far seem to support the general concept that farming by industrialized methods does not lend itself to small scale operations.

At this point it should, however, be mentioned that with pre-pilot plant scale vertical column a conversion of solar energy of 2.5 per cent, conservatively estimated, was attained. This may be compared to the 0.1 to 0.5 per cent conversion attained by conventional methods of agriculture. The production calculated to about 40 tons of dry, high protein Chlorella per acre per year of illuminated area, and this may be compared with about one-half ton of soybean per acre per year.

As yet we have not a complete understanding of the value of Chlorella as a product, chiefly because large amounts of material are required in order to make extensive tests and such quantities have not yet been available. The cells as first separated contain about 75 per cent of water, and for storage such material would probably have to be dried. As has been stated, the composition of Chlorella can be varied at will so that either high protein, up to 55 per cent, or high lipid, up to 85 per cent, can be obtained. This makes it of interest as a source of high protein feed material and a source of industrial raw materials. The protein content of Chlorella is above that of other vegetable materials used as stock and poultry feed such as soybean meal, cottonseed meal, and cereals. The analyses show the presence of all of the ten so-called essential amino acids in favorable comparison with, e.g., soybean protein with the exception of a lower methionine content. The vitamin content of dried Chlorella is high in comparison with other major feed materials. The most notable feature of the fats of Chlorella is their high degree of unsaturation. About 25 per cent of the total fatty acids are C_{16} unsaturated acids and over 50 per cent are C_{18} unsaturated acids, both containing a fair proportion of triply unsaturated acids. It must, or course, be borne in mind that cells high in protein are the most rapidly grown, whereas cells high in fats require considerably more time for development.

As has already been indicated, the most important consideration of any undertaking such as has been here discussed is whether it is economically practical. Studies which have already been made have shown that the large-scale production of Chlorella, or some similar organism, is technically feasible so far as the biological and engineering aspects are concerned. In both of these aspects there exist definite possibilities for various types of improvement over existing practices. There remain many basic questions concerning operation, types and costs of material and equipment as well as maintenance charges still to be answered. Consequently it is impossible at present to arrive at a reliable estimate of the cost of producing Chlorella commercially. In the form in which the undertaking has up to now been envisaged it seems clear that the capital investment in a plant for the production of Chlorella would be very large as compared with that required for the production of the usual agricultural crops. In brief this is primarily due to:

1) The low population density of Chlorella at maximum growth conditions entailing the handling of huge quantities of water.
2) The necessity of maintaining sterile conditions.
3) The cost of materials of construction of the culture system, and to some extent the cost of operation.

As has already been stated, basic improvements to meet these critical problems may result from further research of a biological and engineering nature.

It is of the fundamental nature of an undertaking of this kind that high efficiency can be attained only on the basis of very large scale, continuous operation. Present estimates, with all the uncertainties necessarily inherent in them, indicate that a plant producing 50 tons of dry Chlorella per day would require a capital outlay of approximately $45,000,000. Whether such an undertaking could attract private venture capital or whether other means of initial support will be necessary depends in a large measure on the development of uses of the product, on world food economics and how critical the world food problem becomes. It should be stressed that we are only at the beginning of what is a different system of utilizing photosynthesis. Further basic researches on several aspects of the process can contribute much to a new means of food production.

PRODUCTION OF NUTRITIVE SUBSTANCES FROM INEDIBLE CARBOHYDRATES

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INTRODUCTION

PRODUCTION of adequate food supplies is or should be one of the chief concerns of every country. Thus far, we in the United States have not had to worry about the feeding of our people. We, fortunately, have vast amounts of fertile land per capita, a capable farm population, modern efficient equipment and farm methods, and a highly efficient transportation system. Our population, however, is increasing considerably, much valuable farm land is being ruined by erosion, and water tables are declining. These facts, combined with our observations of the starvation all around us in war-devastated countries, should make us examine the problem soberly, not only from the standpoint of maintaining our living standards, but also with the object of being helpful to the less fortunate peoples of the world.

During the last two decades, with the exception of the World War II years, we in the United States have been faced with the economic problems of overproduction of food. An increased demand for 10 per cent more food or an equal decline in production due to drought or other causes can, however, easily shift us from a position of overproduction to one of shortages.

We have about 450 million acres of tillable land in the United States. This could be materially increased only at the cost of losing valuable timberland or by resorting to expensive irrigation. Farming could, of course, be greatly intensified and shifts made to the production of more grain for human consumption and less for animal consumption. Cattle production is not only an inefficient means of land use from the standpoint of the large grazing areas required per pound of meat produced, but also from the standpoint that cattle consume about 10 pounds of digestible food to produce 1 pound of meat. Cattle, however, return valuable fertilizer to the soil. Further, the people of the United States would shift to the high-carbohydrate type of diet common in Oriental lands only under the direst need.

The people of the United States consume about 100 million tons of food per year on the basis of the retail weight as purchased (0 to 65 per cent refuse; 0.68 ton per capita per year, 3.7 pounds per capita per day, or about 1.2 pounds dry weight of edible food material per day) (29, 30).[2] It has been estimated that at least twice this amount of agricultural plant material is wasted each year (27). Although considerable nutritive material is wasted in handling and processing food before it reaches the consumer, the chief waste consists of the undigestible portions of the plants. About half of this waste is needed for return to the soil (27). The other half could be used as a food if it could be made digestible.

The vast amounts of sawmill and woods residues that occur annually fall in this same category. The total annual wood residue, including standing timber lost due to fire, insects, and storm, amounts to more than 100 million tons on a dry-weight basis (28). Of this about 40 million tons are in the form of readily available mill residue (28). Besides these sources of inedible carbohydrate, we are wasting approximately 5 million tons of hemicelluloses per year in paper mills by either discharging this material into streams or burning it as inefficient fuel. We thus have vast amounts of inedible plant material available for conversion to edible products.

DIGESTIBLE PORTIONS OF PLANTS

The fibrous structural parts of plants are made up chiefly of cellulose and lignin. Softwoods (coniferous species) contain about 65 to 70 per cent of holocellulose (total carbohydrate consisting of true cellulose plus hemicelluloses) and 24 to 28 per cent of lignin on a dry-weight basis.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Numbers in parentheses indicate references at end of article.

Hardwoods (broadleaf or deciduous species) contain about 70 to 76 per cent of holocellulose and 18 to 23 per cent of lignin. The remainder is largely extractives, consisting principally of tannins, related compounds and various natural resins together with inorganic ash. The sugar and protein content of wood is negligible.

The stalks or straw of agricultural plants contain from about 60 to 70 per cent holocellulose (including insoluble starches) and 12 to 22 per cent lignin. They contain more water-soluble extractives than wood in the form of sugars and soluble starches.

Lignin, tannins, and natural plant resins have no food value. There is, further, little hope on the basis of present knowledge of ever converting these materials into foods. Attention will hence be focused on the carbohydrate portion of plant materials. Although true cellulose is a carbohydrate, it differs from starch in that it is entirely undigestible by humans. Starch is readily broken down into glucose sugar under the relatively mild hydrolytic conditions which exist in the digestive systems of animals. Cellulose, on the other hand, requires such drastic hydrolytic conditions to break down the long molecular chains of anhydroglucose units into glucose that it is not accomplished to a significant degree in the digestive systems of any animals. Hemicelluloses, which consist of considerably shorter molecular chains of several different anhydro sugar units (glucose together with other hexoses and several different pentoses), hydrolyze considerably more easily than true cellulose but not so readily as starch. Ruminants can digest a small part of the hemicelluloses. The limited digestibility of hemicelluloses is due to the fact not only that they hydrolyze more slowly than starch, but also that the pentose sugars, which make up a sizeable part of the sugars produced, are digestible only by ruminants. Pentosans, the pentose-sugar-producing part of the hemicelluloses, make up 23 to 28 per cent of the dry weight of the more common agricultural residues, 18 to 25 per cent of hardwoods, and 8 to 13 per cent of softwoods.

CONVERSION OF CELLULOSIC MATERIAL TO SUGARS

Although the bulk of the residual portions of agricultural plants has a low food value and wood has a negligible food value, the carbohydrate portions of these materials can be largely converted to sugars by a hydrolysis process. All the sugars formed are digestible by ruminants and the major portions of them are digestible by all animals. As less pentose sugar, which is digestible to a high degree only by ruminants, is produced from softwoods than from hardwoods, and less produced from hardwoods than the abundant agricultural residues, softwoods should be preferable to hardwoods and hardwoods preferable to agricultural residues for the production of sugars for general feeding purposes. Wood has another distinct advantage over agricultural residues for the production of edible sugar in that large quantities are available at mills without high collection costs and they are available the year around rather than seasonally It would thus seem more economical to concentrate all early efforts in converting nonedible plant material to food to the processing of wood, and pulp mill waste liquors which are readily available. The processing methods and costs, together with economic considerations here described are, hence, those specifically developed for wood. They can, however, with minor modifications be applied to agricultural residues.

The conversion of cellulose to sugars by hydrolysis has been known and studied for over a hundred years. The accumulated information was first put to commercial use in 1913 when a plant was built to hydrolyze southern pine mill waste at Georgetown, S. C., using the so-called American process in which wood was hydrolyzed in a rotary steam-heated digester, using 2 per cent sulfuric acid as the catalytic agent and temperatures up to 175° C. The resulting dilute sugar solution, obtained in yields up to 25 per cent by a single digestion, was fermented to produce 5,000 gallons of ethyl alcohol per day. This plant, and a second at Fullerton, La., operated successfully until 1923. A large drop in the price of competitive blackstrap molasses and an increase in the cost of wood residue due to the necessity of collecting it over a greater area made operation no longer profitable.

Continued research, concentrated mostly in Germany, finally led to the German Scholler process (25, 26) in which multiple digestions were carried out with dilute sulfuric acid in tall stationary digesters. Yields of 40 to 50 per cent of sugar were obtained in concentrations of 3 to 3.5 per cent in 18 to 24 hours. Several plants operated in Germany through World War II on the production of wood sugar for alcoholic fermentation.

The Bergius process (2), another German process developed at about the same time, uses concentrated hydrochloric acid as the hydrolytic agent in special acid-resistant equipment. Although this process gives a cleaner sugar solution from which dextrose can be more readily crystallized in somewhat higher yields, it is necessary to recover the acid for re-use, which makes the process expensive.

A means of hydrolyzing wood, using sulfurous acid, has been developed in Finland through the pilot-plant stage for the production of crystalline dextrose (1).

Work on the hydrolysis of wood to sugar was revived at the Forest Products Laboratory during World War II. A pilot plant built for working out operating details of the Scholler process was used in studying a broad range of hydrolysis conditions. It was shown that, under the Scholler operating conditions, the carbohydrates were almost completely converted to sugars but the product was subjected to high temperature for so long a time that a large part of the sugars formed were decomposed. This information led to the development of the Madison Wood-sugar Process (13, 15) in which dilute sulfuric acid (0.4 to 0.6 per cent concentration) is continuously percolated through the charge of subdivided wood waste, while at the same time gradually raising the steam pressure to increase the temperature from 150° to 185° C. Continuous percolation decreases the time that the sugar formed continues to be subjected to acid and heat. Starting the hydrolysis at a lower temperature allows the sugars which are most easily hydrolyzed from the hemicelluloses to be removed from the system before appreciable decomposition can take place. By these simple changes in operation procedure, higher yields of undecomposed sugar and higher sugar concentrations are produced in 4 hours than were obtained in 18 hours, using the Scholler procedure.

By stopping the percolation when the final sugar concentration falls below 1 per cent, it is possible to obtain average sugar concentrations of from 4.0 to 5 per cent in yields of 45 to 55 per cent from bark-free woods on an oven-dry weight basis. Bark may be included with the wood, but it decreases the yield materially. For example, bark-free Douglas-fir chips give a yield of 52.5 per cent sugar, whereas the mill waste, containing around 30 per cent of bark, gave a yield of only 38.7 per cent.

The acid in the sugar solution is neutralized with lime and the insoluble precipitate of calcium sulfate filtered off. Calcium sulfate, unlike most salts, is less soluble when hot than when cold. It is thus advantageous to neutralize and filter the solution while it still is under steam pressure to avoid subsequent scaling of the evaporator tubes.

The neutral sugar solution is then evaporated to a molasses containing approximately 50 per cent of sugar by concentrating tenfold. Such operations are not as costly as they used to be, owing to the high efficiency of present-day multiple-effect evaporators. It is thus possible to produce a ton of molasses from a ton of wood waste on a dry, bark-free basis.

Several hundred tons of wood-sugar molasses have been made in the small pilot plant at the Forest Products Laboratory by this method for feeding tests and the production of chemicals and yeast (10, 13, 14) (first in a digester with a capacity of 400 pounds of wood and later an improved digester with a capacity of 800 pounds of wood). A larger pilot plant, using a similar digester with a capacity of 1 ton of wood, has been operated experimentally by the Tennessee Valley Authority for about a year in cooperation with the Forest Products Laboratory.

WOOD-SUGAR MOLASSES AND DEXTROSE SUGAR

Table 1 gives an average chemical analysis of wood-sugar molasses (14). This will, of course, vary somewhat with the species of wood used and the extent and conditions of evaporation.

Wood-sugar molasses has a slightly sweet but chiefly bitter taste, similar to that of blackstrap molasses left as a residue from cane sugar manufacture. It is palatable to cattle but not to humans. The bitter components can be largely removed by passing the sugar solutions

TABLE 1

COMPOSITION OF WOOD-SUGAR MOLASSES (14)

Components	Weight *per cent*
Total solid matter	60–62
Reducing sugars (calculated as glucose)	48–50[a]
Non-sugar organic matter	6–8
Ash	2–3
Volatile organic acids	1–2
Nitrogen	0.065
Insoluble fiber	None

[a] Softwoods, such as Douglas-fir, contain 85 per cent hexose sugars and 15 per cent pentose sugars. Hardwoods, such as maple, contain 65 per cent hexose sugars and 35 per cent pentose sugars.

through various filter beds, and can be completely removed by crystallizing out the dextrose (or glucose) sugar. This can be accomplished much more completely than the crystallization of sucrose from blackstrap molasses. When the wood-sugar molasses is concentrated to between 60 and 65 per cent sugar content and seeded with dextrose crystals, a large part of the dextrose can be crystallized out in one operation. The recovery of over half of the sugar in crystalline form in this way should not be expensive, leaving a residual molasses for cattle feeding.

Dextrose is not so sweet to the taste as is common sucrose sugar. It is, however, equally digestible by humans. At the present time it is chiefly used in confections, in wine fermentation, and as the raw material for the production of chemicals. These uses could, however, be greatly expanded.

Extensive feeding tests during the past two years have shown that wood-sugar molasses is an excellent animal food (14). Cattle and dairy cows like it and have shown excellent gains in weight and milk production when fed 3 to 6 pounds per day per head. It has been successfully used when added to low food-value straw, as a binder in pelleted foods, and as a preservative for silage. In all these applications it has proven to be equivalent to blackstrap molasses. It does not have the laxative effect of beet-sugar molasses. Like blackstrap molasses, it has about 70 per cent of the carbohydrate food value of corn (21). Wood-sugar molasses contains no protein. Like corn, it is thus important to feed it together with protein-containing feeds; or for ruminants, molasses might be made a more complete food by adding urea or ammonium sulfate. These nitrogen-containing compounds are converted to proteins by enzymes in the digestive systems of cud-chewing animals to the extent of furnishing one-third of the required protein. Experiments are under way to determine the increased food value for cattle of wood-sugar molasses that is neutralized with ammonia instead of with lime prior to concentration. This eliminates the necessity of filtering the wood-sugar solution and avoids liming of the evaporators. About half of the cost of this more expensive neutralizing agent can be absorbed by the simplification of the process. The other half of the increased cost should be justified by its greater food value for cattle.

Wood-sugar molasses has also been successfully fed to sheep, pigs, and poultry on an experimental basis. Sheep eat it readily, show normal gains in weight, and remain in good health. Wood-sugar molasses was found to be suitable for swine only when it made up 15 per cent or less of the diet. When fed in higher concentrations, it was unpalatable. As swine are non-ruminants, they do not digest the pentoses, so that molasses made from softwoods is preferable to that made from hardwoods. Chickens and turkeys have been successfully fed wood-sugar molasses to the extent of 20 per cent of the carbohydrate in their rations (14, 20). Feeding as little as 7.5 per cent of the total ration as molasses caused a small increase in the egg production of pullets (14).

YEAST GROWN ON WOOD SUGAR

A protein feed high in vitamin B components can be produced from wood sugar by growing various yeasts and molds on the sugar solution (5, 7).

The growth of yeast on sugar has been practiced for years in making both baker's and brewer's yeast. When a live yeast culture is added to a dilute sugar solution containing small amounts of nitrogen and phosphorous components that are needed in yeast metabolism, two different processes can take place. When the culture is not aerated (anaerobic conditions) the yeast cells produce ethyl alcohol and carbon dioxide with a small increase in yeast cells (19). When the culture is highly aerated (aerobic conditions) many more yeast cells are grown and no alcohol is produced (19). The yield of dry yeast cells may be as great as 50 per cent of the weight of the sugar upon which they are produced. The vigor of growth depends largely upon the efficiency of aeration.

Recently equipment has been developed that aerates the culture so efficiently that yeast cells grow rapidly enough to avoid automatically contamination that might be caused by the growth of stray organisms. The Waldhof propagator (6, 12, 16, 17, 23, 24), developed in Germany and commercially used in that country for growing yeast on wood sugars during World War II, has proved to be the most efficient and foolproof method of those tested at the Forest Products Laboratory. Air is mechanically dispersed into a yeast-sugar solution slurry by a rapidly rotating open-tube sparger that also acts as a pump to force the circulation of yeast and the dispersion media through a central

draft tube. Sugar solution is continuously fed into the propagator and the yeast continuously withdrawn. The pilot-plant propagator of the Forest Products Laboratory has a capacity of 40 gallons. When 4.4 gallons of 5 per cent sugar solution are introduced per hour and 2½ cubic feet of air per minute, about 20 pounds of yeast are produced in 24 hours.

A commercial-sized propagator of this type is now being operated at the Rhinelander Paper Company for the production of *Torula utilis* yeast from the sugars contained in the sulfite waste liquor. Under proper operating conditions the yeast growth utilizes a quantity of the sugars sufficient to reduce the biological oxygen demand of the effluent by 50 to 70 per cent. Yeast propagation is thus a promising means of reducing stream pollution.

TABLE 2

COMPOSITION OF TORULA UTILIS GROWN ON SUGAR FROM VARIOUS SOURCES[a]

Components	Source of sugar		
	Pulp liquor	Wood hydrolysis	Blackstrap molasses
Crude protein, per cent	50.4	54.2	46.7
Crude fat, per cent	5.14	3.76	5.82
Ash, per cent	9.53	5.56	7.66
Phosphorus, per cent	2.08	1.19	1.81
Calcium, per cent	.90	.14	.13
Thiamin, mcg. per gm.[b]	5.6	6.9	9.9
Riboflavin, mcg. per gm.	47.9	80.8	39.8
Biotin, mcg. per gm.	2.4	2.3	3.4
Niacin, mcg. per gm.	443.0	450.0	402.0
Pantothenic acid, mcg. per gm.	41.7	134.4	50.8
Pyridoxine, mcg. per gm.	35.5	38.3	43.3

[a] Data of Dr. A. J. Wiley, Sulfite Pulp Manufacturers' Research League, Inc.

[b] Micrograms per gram.

Most recent efforts to grow a food yeast have been centered upon the growth of *Torula utilis* yeast (6, 12, 16, 17). This is a hardy strain of yeast that is easy to grow. Table 2 gives the composition of this yeast grown on three different sugar media including two from wood (14). The protein content of the yeasts can be varied somewhat by changes in the amount of nutrient added, and the growth conditions. The mineral content will, of course, vary with the natural mineral contents of the sugar and that introduced through processing. The vitamin contents of commercial baker's and brewer's yeast are given in table 3, for comparison. The tables show that *Torula utilis* grown on the sugar from wood hydrolyzates and sulfite waste liquor compare favorably in vitamin content with commercial baker's and brewer's yeasts in all cases but thiamin. Fortunately, this vitamin is supplied in adequate quantities by several common foods, such as cereals, whole wheat bread, beans, peas, and pork (30).

TABLE 3

VITAMIN CONTENT OF COMMERCIAL YEASTS (22)

Vitamins	Baker's yeast			Brewer's yeast	
	Compressed active	Dry active	Foil	Unde-bittered	De-bittered
	mcg. per gm.			*mcg. per gm.*	
Thiamin	11–60	7–29	88–139	110	104–250
Biboflavin	25–80	31–70	57–59	38	25–80
Biotin	0.8–2.4	0.43–1.52	0.57–1.47	1.1	1.1
Niacin	293–482	180–351	256–336	400	300–627
Pantothenic acid	150–280	100–150	131–157	80	72–86
Pyridoxine	25–39	—	—	31	23–40

Yeast is used in the United States primarily to supply the vitamin B compounds (3). It could also be fed for its protein value. Tests were hence recently made at the Forest Products Laboratory to determine the relative food value of several different strains of yeast.[3] Table 4 gives a summary of the data obtained in growing six different strains of yeast on wood sugar produced from the hydrolysis of

[3] Harris, E. E., G. J. Hajny, and M. C. Johnson, Continuous production of six strains of yeast on wood hydrolyzate and protein evaluation. Prepared in cooperation with H. T. Scott and C. H. Krieger of the Wisconsin Alumni Research Foundation for presentation to the American Chemical Society, Sept. 5–8, 1950, Chicago, Ill.

TABLE 4

A COMPARISON OF SIX STRAINS OF YEAST GROWN ON ASPEN WOOD SUGAR

Strain of yeast	Maximum rate of feed	Sugar utilized	Yeast		
			Cell volume	Dry yield	Protein content
	liters per hr.	*per cent*	*milliliters per 100*	*per cent*	*per cent*
Torula utilis No. 3	18	95.0	10	46	50.7
Candida krusoides	18	95.0	12	45	45.4
Mycotorula lipolytica	16	94.0	11	51	46.1
Torula utilis thermophilis	16	94.8	11	50	47.6
Candida aloicans	12	93.0	11	49	47.2
Saccharomyces cerevisiae No. 46	14	96.0	9	42	50.7

aspen. The rate of growth, completeness of sugar utilization, yield, and protein content are very nearly the same for each. Table 5 gives a summary of the food value of these different strains of yeast compared with casein as a standard, together with data for *Torula utilis* grown on sulfite waste liquor, brewer's yeast, the fungus *Fusarium lini* and soybean meal, on the basis of the gain in weight of protein-depleted rats, using the method of Frost and Sandy (9). The data show that with the exception of brewer's yeast, all of the yeasts and the *Fusarium lini* showed appreciably lower nutrient value than casein and slightly less than soybean meal. It was suspected that this was due to lack of some growth factor, such as the amino acid methionine in the protein (5). This was shown to be the case. When methionine was added to the extent of 0.09 gram per rat per day to the normal diet of 15 grams of ration per rat per day, the nutrient value of all the protein feeds became similar. As methionine is now being produced commercially at a reasonable cost, it could readily be added to yeast. On this basis there is little choice between different strains of yeast, both from the growth and the feeding standpoints.

TABLE 5

ASSAY OF THE PROTEIN OF VARIOUS FOOD YEASTS AND FUSARIUM AS COMPARED TO CASEIN BY RAT REPLETION METHOD

Protein	Run no.				
	1	2	3	4[a]	5[a]
	Gain per rat per day				
	grams	*grams*	*grams*	*grams*	*grams*
Torula utilis No. 3	3.1	3.1	2.7	6.2	5.2
Sulfite yeast	3.1	3.5		5.8	
Candida krusoides	3.2	2.8		5.9	
Torula utilis thermophilis	3.0	3.1		6.2	
Candida aloicans	4.2	3.5		6.6	
Saccharomyces cerevisiae	3.6	3.7		6.1	
Mycotorula lipolytica	3.7	3.4		6.6	
Brewer's yeast	5.2	5.3		6.5	
Casein	5.0	5.5	5.3		5.6
Casein	6.4	4.9			
Soybean meal			4.4		7.3
Fusarium lini, Bolley No. 5140			3.4		6.5
Fusarium lini, Bolley			2.9		5.3

[a] With methionine.

The common strains of yeast grown under normal conditions usually contain 2 to 6 per cent of fat (18). These fats consist of glycerides of oleic, palmitic, and stearic acid (normal fats), together with stearols and phospholipides (18). The stearols, chiefly ergosterol, can be irradiated to build up the vitamin D content of the yeast.

The fat content of yeast can be built up by modifying the growth conditions. A few strains of yeast have been found that are especially adapted to fat production (4). Strains isolated from soil have been propagated under conditions such that they contain as high as 60 per cent fat. The growth of this type of yeast is now being studied at the Forest Products Laboratory on wood sugars in the Waldhof propagator. Yeasts containing as much as 25 per cent of fat, it appears, can be grown at rates approaching the rate of growth of normal yeasts. Considerable more research will, however, be needed to determine the food value of such yeast and the practicality or its growth.

ECONOMICS OF FOOD PRODUCTION FROM NON-EDIBLE CARBOHYDRATE WASTES

It is intriguing to know that wood and agricultural residues that have little or no food value can be converted to digestible sugars, proteins, and fats, and that the proteins contain essential vitamins of the B group and the fats can be irradiated to produce the D vitamin viosterol. The importance of this knowledge for present use, however, depends upon the economics of the conversions.

MOLASSES

On the basis of pilot-plant studies, it has been estimated that the smallest practical molasses plant based on present methods would have to process 50 tons of wood waste per day on a dry-weight basis (11, 14). Such a plant would cost about $300,000 (14). If the plant were amortized in 4 years, with wood waste valued at $2 per ton on a dry-weight basis and labor costing on the average $10 per day per man for 15 men (5 per shift), then the cost of production would be about 10 cents per gallon or $17 per ton for molasses with a sugar content of 50 per cent.

This production cost appeared quite favorable two years ago when competitive blackstrap molasses prices were high. A little over a year ago the price of Cuban blackstrap molasses dropped to the low figure of $10 per ton in New Orleans.[4] High shipping costs, however, made the price $22 per ton in Chicago and

[4] Report of L. J. Kutish on The marketing of feed molasses, prepared for the Production and Marketing Administration.

$25 per ton in Minneapolis.[4] Even in lumbering regions quite distant from ports of importation no profit could be made on wood-molasses manufacture if it had to compete with this low price of blackstrap molasses. Such prices, where the Cubans obtained only a little over a cent a gallon for their molasses, are, it is felt, quite abnormal and higher stable prices can be expected. Although the price of blackstrap molasses has increased somewhat recently, it would still be risky to build a plant in any but the most remote places from ports of importation. If the price of blackstrap molasses were to increase on a rather stable basis to $15 to $20 per ton in New Orleans (50 to 100 per cent above the lowest recent prices), wood-sugar molasses production might be profitable in several regions.

The amount of blackstrap molasses available for feeding, although amounting to over 100 million gallons, or 600,000 tons per year (8), if fed only to beef cattle and dairy cows at the low level of 3 pounds per head per day, would last only a few days. The price of blackstrap molasses could thus control the price of wood-sugar molasses only during the early stages of the development of molasses feeding on a large scale. Ultimately the price of corn would control the price of wood-sugar molasses. It has been estimated that a bushel of corn is equivalent in food value to 6½ gallons of molasses (21). If it is assumed that profit plus sales cost, f.o.b. plants, makes the market price of wood-sugar molasses double its manufacturing cost, then wood-sugar molasses at 20 cents per gallon would be equivalent to corn at $1.30 a bushel. At distances from the plant to which transportation charges would be $15 per ton, the comparable price of corn would be $1.90 per bushel. Under present conditions where the prevailing price of corn is around $2 per bushel, wood-sugar molasses feeding would be profitable in a number of regions. Although it does not appear profitable to start the manufacture of wood-sugar molasses under present economic conditions, if the industry were well established it could in all probability continue to operate successfully under these conditions.

It is of interest to consider how much wood-sugar molasses might be made if its feeding became practical. If all present sawmill residue were converted to molasses, the 40 million tons of such residues would produce roughly 40 million tons of molasses. This is about 67 times the present blackstrap molasses consumption for feeding purposes. It would be enough to feed all beef cattle and dairy cows in the United States 3 pounds of molasses per day for 7 months of the year. More molasses could be produced if woods waste and agricultural residues were collected for conversion to molasses but the cost would be materially increased. If, for example, the collection cost, including hauling to the plant, were $8 per ton, the manufacturing cost of the molasses would be increased from $17 per ton to $23 per ton.

DEXTROSE

More experimental work will have to be done on the crystalization of dextrose from concentrated wood-sugar solutions before the cost of the process can be estimated with any certainty. It is probable, however, that a large part of the dextrose could be isolated from molasses in quite pure form for an operational cost of about 1 cent a pound. A gallon of molasses with a sugar concentration of 50 per cent contains about 6 pounds of sugar. On the basis of a molasses production cost of 10 cents per gallon, the sugar it contains would be worth 1.7 cents per pound. Adding 1 cent per pound for purification and 100 per cent for sales cost and profit, the sugar could be sold for 5.4 cents per pound. This price is slightly below present wholesale cane-sugar prices, but not enough so to warrant extensive dextrose production from wood waste at the present time.

YEAST

No accurate figures are available on the cost of yeast production from wood waste at the present time. The Lake States Yeast Corporation at Rhinelander, Wis., however, is able to sell *Torula utilis* yeast grown on sulfite liquor for about 10 cents a pound on a wholesale basis. Although the sulfite waste liquor is costing the plant nothing, it must be steam stripped of sulfur dioxide, neutralized, and filtered. These processing costs, combined with the fact that the liquor provides a considerably more dilute sugar solution (about 1 per cent concentration compared to 5 per cent for the hydrolyzed-wood liquor) would make it appear that yeast made from hydrolyzed-wood waste could be sold for about the same price.

Most common protein foods, with the exception of soybean meal, are more costly than this. Soybean meal is now selling on a wholesale basis

for about 3.5 cents a pound. It contains about 43 per cent protein and 43 per cent carbohydrate, together with 10.7 micrograms per gram of thiamin, 3.1 micrograms of riboflavin, and 23 micrograms of niacin. The protein content of *Torula utilis* yeast made from wood hydrolyzates is about 15 per cent higher than that of soybean meal, the riboflavin content is 10 to 30 times as high, and the niacin content is 20 times as high. On the other hand, the thiamin content is only 50 to 70 per cent as high. On the basis of relative protein content alone, the price of the yeast should not exceed 4 cents per pound. The present economic possibilities of yeast production from wood sugars thus rests upon the sales value of the high riboflavin and niacin content. Further feeding tests are needed to determine this.

CONCLUSIONS

It is shown that large amounts of edible molasses and dextrose sugar can be produced from such non-edible carbohydrate wastes as sawmill waste, woods waste, and various agricultural wastes at prices which are but slightly greater than present economic conditions would allow.

Yeast containing high concentrations of food protein that can be made almost entirely available by the addition of small amounts of methionine can be readily made from the sugars existing in the waste liquors of the sulfite pulping process and fruit wastes. It can also be made from the hydrolyzates of wood and agricultural wastes. Next to soybeans, this appears to be the cheapest source of proteins. The higher riboflavin and niacin content of yeast compared to soybeans, however, may increase its food value sufficiently so that yeasts could be fed at a much higher level than at present to animals and humans.

Present development work on the growing of special fat-producing yeasts on sugar and their irradiation to produce the D vitamin viosterol indicate that this means of producing fats from carbohydrates may become of importance some time in the future.

All these approaches are definite possibilities for helping to feed the world in the not-too-distant future.

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ON INCREASING THE EXPLOITATION OF AQUATIC RESOURCES FOR WORLD FOOD NEEDS

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IT IS difficult for meat-eating people like Americans to think seriously about fish as an important article of diet, for the use of fish which most touches our sentiments is recreation. Yet there are countries where people think with dead seriousness about a handful of minnows, not as bait, but as the only flesh they will have for several days to balance their monotonous vegetable fare. As our population grows, we, too, will find fish becoming more and more important in our diet. Therefore, it is important not merely for the distressed countries, but for us, too, to consider how the production of fish might be increased.

Let us begin by agreeing to a few simple statements which are widely accepted as fact:

Everywhere in the world there are people whose physical well-being is below its potential for want of optimal quantity and quality of food.

More than half the people in the world are densely concentrated in areas where the average food supply is far short of being optimal.

Animal protein foods are nutritionally important because of their high "biological value" and their high content of vitamins and minerals. But it takes so much land and costly feeding to produce meat, milk, cheese, poultry, and eggs, as to push such foods far beyond the reach of people living under the pressures of poverty. Therefore, if it is at all possible to produce cheap animal protein in usefully large quantities, the most likely source of it is the food organisms living in water, mostly fish.

In the ocean, many fishery stocks have long been exploited to their fullest productivity (some of them far beyond that point); nevertheless, there remain other, quite primeval stocks of fishes living in the ocean for the taking. In inland areas, particularly in the so-called "backward" countries, fish farming is a very old art; nevertheless it could be expanded wherever there is enough water, even in those countries where it has been longest established and where it is most highly developed.

These potentialities, the untouched or underdeveloped ocean fishery stocks, and the inland areas that could be developed for fish farming, are not distributed uniformly over the earth, nor are they concentrated in any convenient relation to the populations that need them most, or to centers of skilled labor capable of exploiting them. So long as they remain mere potentialities they are of no direct service to human needs. If and when they do finally become exploited, their value will be proportional to the volume and cost of food which they yield. They will be of little importance unless they yield very large volumes very cheaply. This requires the kind of organization which is called *a fishery*, which means a stock of fish, skilled fishermen (or fish farmers), and the complex system of industries—boat building, net and twine manufacturing, preserving, transporting, marketing, and so on, without which the great fisheries cannot exist.

The question which I propose now to explore is this: What problems must be faced and solved in order to generate and develop fisheries in the "backward" countries? Here we need a definition. What is "backward"? There is much preoccupation among humanitarian people today about the inequalities in standard of living between those few populations that are very well fed, and those many populations that live in a way that we North Americans would describe as being intolerably close to destitution and starvation. We describe the one type of population as "backward," and the other as "advanced." But backwardness is not a quantity that can be measured objectively. To us well-fed, industrial-minded people, brought up in a tradition of physical well-being, backwardness is utterly foreign to what Orientals, for example, would associate with the term (if they thought about it at all), living in their ancient

cultures that center around the spirit rather than the flesh. Therefore, for the purposes of this discussion, I will restrict the phrase "backward country" to mean one in which the per caput supply of food is remarkably below optimal biological needs, and where potential food resources could be utilized by the application of appropriate technological effort.

To start this effort is to generate a revolution in custom, a really formidable task. For this it takes men who are genuinely interested, clear-thinking, technically capable, practical-minded, and willing to work actively towards a goal which may be many generations away. At present, the number of available men is very small; in the "advanced" countries, there are certain nuclei of such men, humanitarian and international-minded, who are professionally consecrated to the end of raising the standard of living in the depressed areas. Among these, the number concerned with fisheries development is a small minority even though the fisheries may be the most promising hope of producing cheap animal protein. For example, in the Food and Agriculture Organization of the United Nations, there are no more than twenty men in the Fishery Division; twenty men to introduce new fishery industries, new techniques of fishing and of fish farming all over the world, not to mention changing dietary habits of whole populations! In the "backward" countries there are also a few nuclei of men, who are humanitarian, who have travelled widely, and would like to change the living condition of their compatriots. But the number of those in a position to lead, to be articulate about their hopes, and able technically to transform it to a course of action, is pitifully small. So here is the situation at the outset: a handful of people arrayed against a complex of opposing forces, of which perhaps the greatest is the very magnitude of the number of people they are striving to affect.

The obvious ready answer to this problem is "Education." Hasn't that been successful in countries like North America? Hasn't education (or is the word "advertising"?) taught our producers to improve agricultural methods, and consumers to select and demand balanced diets properly loaded with the whole gamut of vitamins? Doesn't our government issue a remarkable assortment of pamphlets for those purposes? The United States Fish and Wildlife Service, for example, publishes one quarterly journal for fishermen and fish handlers in order to give them technical information on how to improve their methods and another quarterly journal for fish culturists dealing with hatchery practices and fish farming. Why not spread that kind of service everywhere?

But in the "backward" countries the man who needs education to produce more food, the person with whom we are concerned today, is illiterate; he cannot read. If he lives in a rural area, he has never seen a radio nor heard one. His only communication is by word-of-mouth. He is not likely to listen to a speech, or to attend anything like a series of classes, even though they be free. If one is to educate him he must begin with very small groups, perhaps of only three or four. From our point of view, his life is hemmed in from every direction by centuries of tradition; and he will sacrifice any material utility for the sake of the mental comfort which his tradition provides. He is filled with mysterious prejudices, is suspicious of the unorthodox, of novelties, of strangers, and of his own government. If 2,000 calories a day is his optimal biological requirement of food, he gets, *on the average*, only a quarter that amount; but his food supply fluctuates widely around that average so that sometimes he has plenty, sometimes nothing and then he must migrate in search of food, or die. He suffers from chronic deficiency diseases, and from various infections to which his condition has made him susceptible. Sometimes, by our standards, he is lazy. He has no money. He does not think of himself tragically as being badly off unless he is actually starving under a famine. Finally, there is almost infinite variation in all these conditions from one country to another, so that no universal formula can be devised for improving the lot of such people according to our standards.

It goes without saying, then, that a fishery technician having the problem of introducing to an unknown people a new way of producing food, perhaps to them a new kind of food, will meet many resistances. He can begin his task only by invitation of the government of the country in question; for of course a technician cannot push his way into a place uninvited. But the government must do more than merely invite him. It must be *actively* interested in the success of his enterprise. It must be ready to organize and finance a fishery administration for the purpose of fostering fisheries, not for the purpose of merely making more governmental jobs. It must provide whatever facilities are

needed. For fish farming, that means land and labor for construction of the installations. Most of all, the government must continue to support the project permanently, which means it must be so stable that the project will continue in spite of political changes.

Supposing a government has all those desired qualities and has invited a technician to introduce fish farming. Suppose the technician finds on surveying the country that there is ample space for constructing ponds, that the water supply is adequate, and that conditions look promising for pond culture development. What then? Then those sponsoring the technician must resist every temptation, every pressure, to attempt developing the project on a grand scale. The technician has so much to learn himself about the country, the climate, the fauna, the ways and tastes of the people, so many things can go wrong to destroy the whole project, that it is not merely the best thing to do, but it is absolutely essential, to begin the project on a very modest and tentative scale. Two or three local people will be plenty to work with the technician at the start. These he will recruit from among the educated class, and that in itself will take time, for not all educated people whom he interviews will be interested in fishery work or suited to it. When at last he does find promising men, he has the job of training them to take over the fishery administration and the responsibility of continuing the growth of the project after he leaves it.

Here, incidentally, arises a special cultural problem for the technician. Education is a necessary qualification of his newly-found associates. Besides making them literate, it has taught them to think systematically and has advanced them beyond the limitations of folk prejudices. But it has its unfavorable side, for it has given them other sorts of prejudices. Those in the "backward" countries lucky enough to go away for education tend to lose touch with their compatriots. They return conditioned to the foreign country where they studied; they have developed a taste for the culture of cities; they want white collar work; they eschew association with their less favored compatriots; they have withdrawn from the soil. It is the sort of thing that happens in the United States, too, but not to such an extreme degree. So it is that after the fishery technician has recruited the educated men who are to be the backbone of his project, he often must re-educate them to do the kind of dirty work that goes with fish culture. This may take a good deal of time, and patience.

If the little team thus formed is very lucky, it will succeed during its first year in establishing a demonstration center with about ten ponds and a small laboratory and fish nursery. The expenses for the purchase of land, the construction and salaries of the staff can be of the order of $20,000 for the first year. In subsequent years, small groups of carefully selected farmers will be brought to this demonstration center for short periods of training to set up ponds of their own; and gradually other demonstration centers will be established throughout the country. Appreciable results in the form of large production of fish should not be expected for several years. "Pouring in" money cannot speed the process. Success will depend on a happy combination of many circumstances—luck, the sincerity, ingenuity, and aggressiveness of those engaged in the project, the stability of the government, and adequate concomitant development of preserving, transporting, and marketing facilities, and a willingness of the public to eat the fish. The possible rewards are impressive. Dr. S. Y. Lin, of F.A.O. estimates a possible increase in the production of fish by pond culture in several countries as shown in table 1.[1]

TABLE 1

Country	Population in thousands	Estimated potential area for new pond development (thousands of acres)	Estimated yield in thousands of tons
China	420,000	3,700	4,150
India	337,000	2,471	660
Indo-China	25,000	1,235	914
Indonesia	76,000	1,235	338
Japan	80,000	247	57
Malaya	4,000	247	220
Philippine Islands	19,960	1,235	196
Thailand	17,000	247	220

The fishery administration set up for pond fish culture can, in some areas, also foster a fuller use of rice paddies for fish farming. This method depends on the fact that rice culture requires flooding the fields for periods of three to six months each year. By planting fry at the beginning of a flood period, a farmer can harvest

[1] Unpublished MS.

a crop of fish at the end which have grown and fattened on the nourishment furnished by the rotting rice stubble, The method depends on the development of a nursery fry industry, which can be closely associated with farm ponds.

How much extra food might be produced thus we do not know. In some countries, rice paddy fish culture might be already pretty fully developed; but in other countries it could ultimately be extended to produce very large quantities of fish. But here again the development would be impeded by a multiplicity of obstacles, and would take a long period of time.

It is true enough that the cultivation of fish in fresh waters, whether in artificial ponds, in rice paddies, in impoundments back of dams, or in irrigation ditches, can in the course of sufficient time be a most fruitful way of improving the supply of protein food. But this is by methods of long standing conventionality, and may prove disappointing to people who want something more heroic. If we may judge by articles frequently appearing in the magazines and newspapers, what people expect now is more miracles of Science, say an entirely new kind of food that can be produced in massive quantities at negligible cost, which somebody will eat, presumably the backward peoples. If anything so novel could be taken from among the aquatic resources, it would more likely be found in the ocean than in the fresh waters. For in the ocean there is an unknown thing, still unexploited, still unexplored, which may prove to be an extravagantly large food resource. This unknown thing scientists refer to as the "Deep Scattering Layer."

During the Second World War, technologically improved echo sounding instruments disclosed the presence of a layer of something between the bottom and surface, which produces an echo. This layer seems to occur everywhere in the ocean. It moves diurnally, toward the surface about sunrise and sunset, away from the surface during the intervening times. Hilary Moore (unpublished MS. 1950) says,

> Most often there is only a single layer, but on a number of occasions, two or more distinct layers have been recorded, and there is little doubt that improved techniques will allow the separation of such multiple layers more regularly in the future. There may also be layers which do not execute the same type of diurnal migration as the main layers. Finally there is often a very deep layer lying at a depth of about five hundred fathoms, and this may execute a diurnal migration. [See fig. 1.]

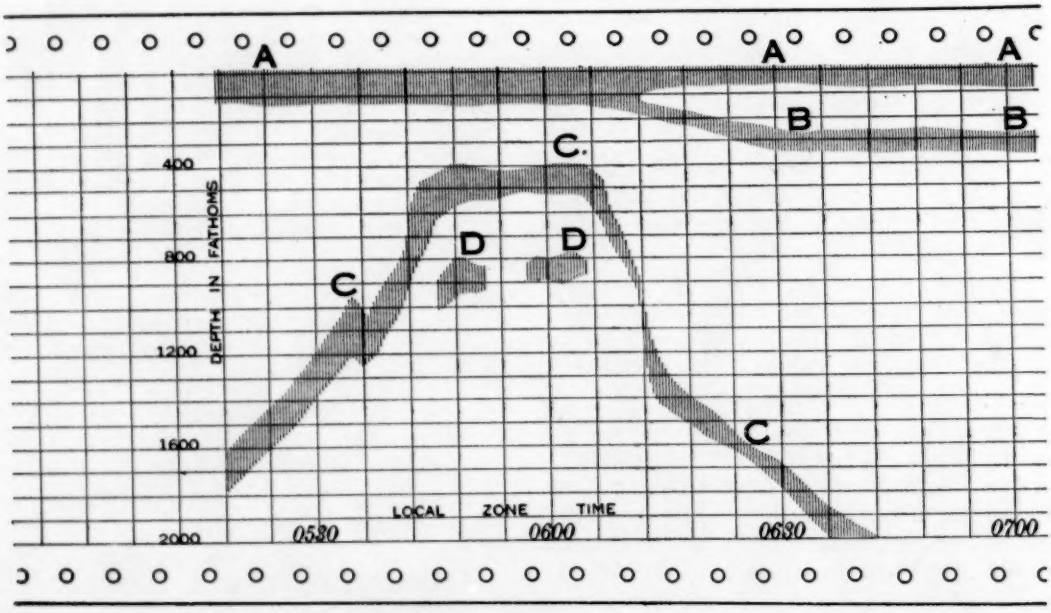

FIG. 1. Line drawing made from a fathogram to illustrate scattering layer.

A. Record of outgoing signal.
B. Record of scattering signal.
C. Bottom.
D. Double echos produced at twice actual depth.

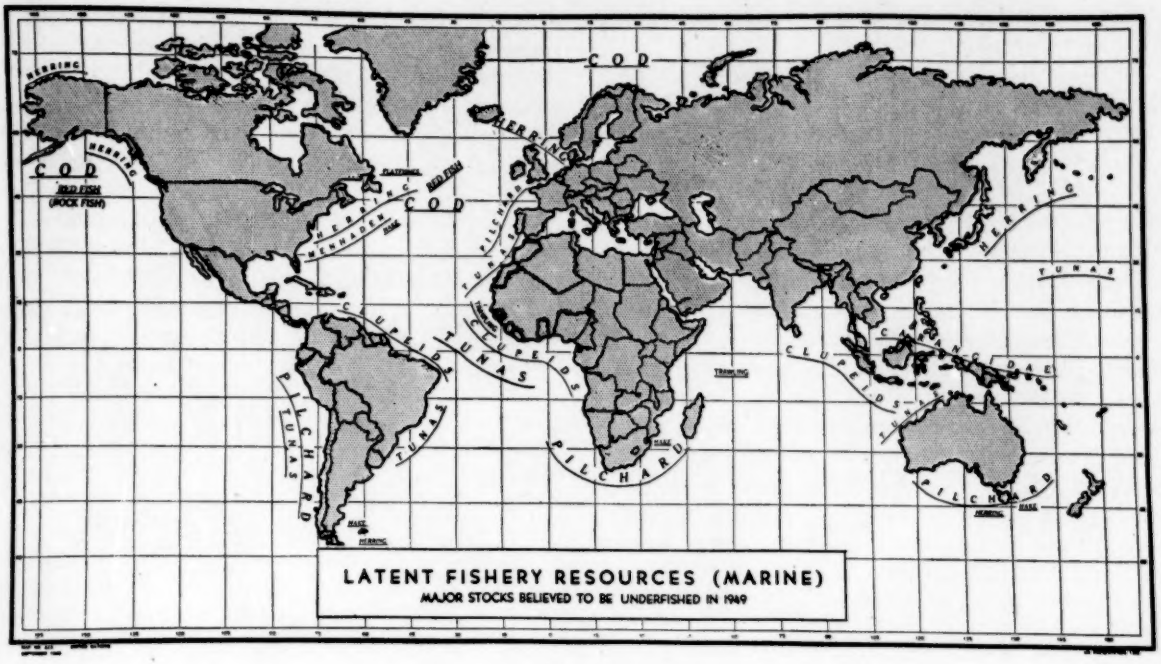

FIG. 2.

Everyone who has studied this phenomenon agrees that it is caused by masses of living organisms. However, the technical problems of determining the composition of these masses are formidable, for it is mechanically difficult to hold nets down to the depths where the layers occur and operate them there. Moreover, the resistance of the water against wire and nets at those depths so depresses towing speeds that any significantly sized organisms could easily elude ordinary fishing gear. Consequently, the composition of the scattering layers remains unknown. Oceanographers vary in opinion as to what composes them; and until they have solved the technical fishing problems they can do no more than speculate as to whether the dominating fauna be fish, squid, prawns, euphausids, copepods, or something still unnamed. Whatever it be, if it is abundant enough and useful enough to be worth exploiting, methods of large-scale fishing would have to be invented resembling nothing with which commercial fishermen have ever had experience. Commercial fishermen are unlikely to invent anything so novel in the foreseeable future. They tend to be conservative. Their techniques advance very slowly in small steps; and they are generally loath to stray far from the areas or the methods which they have found productive enough. They have always exploited only the layers about the bottom and near the surface and in the places which they know intimately. Possibilities of commercial profit in the deep scattering layers are much too uncertain to justify commercial fishermen gambling their money or time to explore it, not to mention the investment it would take to develop some use for whatever they might find.

So far the governments of the "advanced" countries have been too preoccupied with studying the well-established fisheries for conservation purposes to use their very limited research facilities for exploring anything so uncertain as the deep scattering layers. The F.A.O. is unable to undertake such a project, for it has no vessel or any other research facilities. There remains only universities and private research institutions, but at present the exploration of the biological composition of these mysterious layers must await enough money—perhaps something of the order of $100,000—to finance the development of appropriate gear and the operation of a suitable experimental vessel.

The least result to be expected from such a research into the deep scattering layer would be the extension of human knowledge about the earth; the most valuable practical result might be undreamed of quantities of food. Surely

either possibility is worth striving for on an international scale.

Meanwhile, the more familiar resources must be pursued.

We are quite certain that several stocks of ordinary kinds of ocean fishes like cod, herring, sardines, and tunas, are under-fished; and among them are probably virgin stocks not yet touched.

A little over a year ago at Lake Success, the United Nations sponsored a Scientific Conference on the Conservation and Utilization of Resources. There, several fishery experts pooled their information to draw up a chart showing where they believed latent fishery resources to be located; as a minimum estimate, these might yield a minimum increase of about four million tons, which is around 22 per cent of pre-war production (Thompson, 1949). Of this amount perhaps 2.7 million tons could be expected from cold and temperate waters, and about 1.3 million tons from tropical and subtropical waters. (See fig. 2.)

As I said earlier, however, a fishery is a complex organism comprising fish, equipment, and men. It cannot spring into being full grown. It cannot even start developing unless there is a hospitable atmosphere for its growth. The rate of growth of a fishery will depend largely on the development of supporting industries. Wherever a fishery exploits a stock of fish to its fullest capacity or, in other words, has become mature, it has reached that point thanks to a sufficiently large fleet of vessels with skilled fishermen, and adequate vessel building and repairing facilities, harborage and means of keeping the harbors in good order, wharves, machine shops, fuel tenders, freezers, salteries, canneries, net and twine manufacturers, and dealers of all sorts of miscellaneous articles incident to the operation of boats and shore plants. Developing fisheries follow a logistic growth curve such as characterizes the growth of animals, of populations, and of industries that depend upon populations. Under the most favorable conditions it takes several years for a fishery to mature. For example, the pilchard fishery on the Pacific coast of the United States took about twenty-five years to grow from its inception to the point where its yield began to fluctuate around an asymptote of 550,000 tons a year (Schaefer, Sette and Marr, 1950)[2] (see fig. 3). At that point the capital investment in vessels and fishing equipment was perhaps of the order of $17,000,000 in terms of the 1942 value of the dollar. There were 3,039 men engaged primarily in pilchard fishing, and 280 vessels; 38 canneries were in operation for canning pilchards, and 71 factories for manufacturing pilchards into fish meal and oil. The total capital investment in these factories was perhaps something of the order of $60,000,000.[3]

Thus the Pacific pilchard industry, which grew under fairly auspicious circumstances, occupied

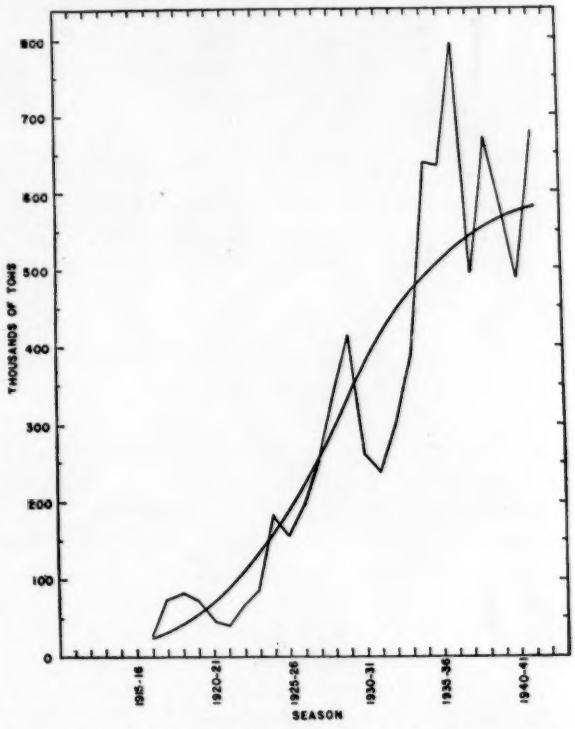

FIG. 3. Total catch of pilchard on the Pacific Coast and fitted trend for the period 1916–17 to 1940–41.

twenty-five years in the growing and involved a capital investment for boats, gear, and factories of *roughly* 77 million dollars to produce an average annual catch of around 550,000 tons. These figures give a general idea of what is required for the development of a great oceanic fishery.

The capital investment required varies widely among different types of fisheries and among different areas, as Richard Kahn has shown in these estimates (table 2).

[2] The non-random, short term fluctuations over the course of this growth curve are closely related to fluctuations in economic conditions.

[3] These figures are based on material furnished by Dr. Richard A. Kahn, Economist, Fish and Wildlife Service.

TABLE 2

Area	Capital investment	Capital investment per fisherman	Tons of fish caught
Washington	$63,638,924	$3,326	98,000
British Columbia	30,913,279	2,528	307,000
Ontario	5,716,075	1,500	15,000
Nova Scotia	15,097,992	1,012	188,000
Manitoba	2,442,628	360	16,000
Northwest territories	292,000	730	4,000
Texas	7,883,000	2,320	28,000
Ceylon	8,775,000	195	40,000
Puerto Rico	458,640	172	2,000

The growth rate of a fishery like any organic growth appears to be a property inherent in the constitution of the organism. It depends on the magnitude of the fish stock, the size of the population of the people utilizing it, the degree of their technical advancement, the amount of capital that can be drawn upon to feed the industry, and a complex of other interrelated elements.

In my opinion the most significant thing people can do to increase the production of aquatic resources for contributing to the world's food needs is to stimulate the inception of new fisheries. Beyond that they might be able to speed up the rate of growth of those fisheries, but only within the rather narrow bounds of the inherent potentiality of each situation. To start a marine fishery involves for the technician about the same kind of sociological, economic, and political problems that he must deal with in starting a pond fish project. The resistances and the prejudices he faces might be different, but they will have the same impeding effect. We should, therefore, not be discouraged if results are slow in appearing. For we are dealing in processes which may run over the course of many generations; but whatever our generation can contribute, no matter how trifling, will make its mark.

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GENETIC IMPROVEMENT OF FOOD PLANTS FOR INCREASED YIELD

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INTRODUCTION

THE paramount importance of food to the lives and well being of all peoples is well recognized. Efforts to obtain adequate amounts of food are a basic consideration in understanding human relations, maintaining peace, or fighting a war. Food is a big factor, in many cases the major factor, in controlling population growth.

The problem of increasing food supply to keep peace with population growth has recently been reviewed by H. R. Tolley (10)[1] who estimates that the world's population probably will have increased by 25 per cent between 1946 and 1960. Tolley also estimates that the food needed by this large population, plus that required to improve general world nutrition to the levels assumed to be necessary, would require that the production of fruits and vegetables be increased 163 per cent, milk 100 per cent, pulses 80 per cent, meat 46 per cent, fats 34 per cent, roots and tubers 27 per cent, cereals 21 per cent and sugar 12 per cent.

Fortunately modern science has provided us with many new tools to aid in increasing food supply to keep pace with population growth. One of these new tools is genetics, the science of heredity, which celebrated its Golden Jubilee at Columbus, Ohio, last month. The subject I have been asked to discuss this afternoon is the genetic improvement of food plants with particular reference to increased yield. This subject is much too broad to treat in detail in the time available. For this reason it seems advisable to select examples from among the major food plants and describe what has been done to improve these plants in specific instances.

The average world production of major crops, exclusive of the U.S.S.R., for the five-year period 1934–1938 and for 1948, as reported in the 1949 FAO *Yearbook of Food and Agricultural Statistics*, is shown in table 1. Because of the importance of grain crops, examples of improvement will be cited for each of the three major crops, wheat, maize, and rice. Examples also will be cited for potatoes, and for sugarcane which supplies roughly three-fourths of the world's raw sugar. Grains are not only a direct source of food, but as livestock feed they furnish much of the raw material for producing milk, meat, and animal fats. Increased yields of cereals may release land for the production of other food crops. For example, the farmers of the United States are now producing more corn on 85 million acres than they formerly produced on 100 million acres.

TABLE 1

WORLD PRODUCTION OF MAJOR CROPS[1]
(In millions of metric tons)

Crop	1934–1938	1948
Wheat	127.0	142.3
Rye	21.0	18.8
Barley	41.1	44.4
Oats	45.0	49.2
Maize	109.6	151.4
Millet and sorghum	46.1	44.9
Rice	148.1	145.4
Total grains	537.9	596.4
Sugar, raw[2]	28.0	32.3
Potatoes	158.8	165.6
Sweet potatoes and yams	37.0	47.0
Total pulses[3]	20.0	21.4
Total oilseeds[4]	41.4	49.1

[1] Exclusive of the U.S.S.R.
[2] Includes beet and cane sugar.
[3] Includes dry beans, dry peas, broad beans, chick peas, and lentils.
[4] Includes soybeans, peanuts, cottonseed, linseed, hempseed, rapeseed, sesame, and sunflower seed.

Accurate determinations of increased production resulting from genetic improvement in the yielding ability of crops are difficult to obtain. The two sources of pertinent data are: (1) the results of replicated trials in experimental plots, and (2) the estimates of increased production on farms. Replicated experimental comparisons of new and old varieties have the advantage of

[1] Numbers in parentheses indicate references at end of article.

yielding fairly accurate data on relative production under the environment of the experiments. They have the disadvantage in that relatively few environments and cultural practices usually are sampled. Conversely, the data on farm production have the advantage of a wide sampling of environments and cultural practices. They have the disadvantage, however, of being based on less precise determinations of yield, and of the genetic effects frequently being confounded with those of concurrent changes in cultural or other production practices.

In spite of the difficulties of precise interpretation, the data on farm production seem to have some advantages and have been used in preference to those from experimental yield comparisons. These data should better reflect the full accomplishment of genetic improvement, whether operating alone or in combination with improvements in cultural practices.

WHEAT IMPROVEMENT

Wheat is the principal bread grain of the world and the record of wheat improvement in the United States is one of outstanding accomplishment. Quisenberry (3) recently estimated that new wheat varieties produced by experiment stations and grown by farmers are responsible for an increased production of about 170,000,000 bushels per year above what would have been possible with the varieties available twenty-five years ago.

Wheat improvement in the United States has centered around two main problems, the development of varieties resistant to rust, and the development of early drought-resistant varieties which would permit the extension of wheat culture into the dryer regions of the north and the west. Fifty years ago the only varieties of hard red spring wheat available were Red Fife, Haynes Bluestem, and selections from them. These varieties produce good yields under conditions of abundant rainfall and absence of disease. Such conditions are seldom encountered, however, in the great wheat-growing regions of the Midwest.

The spring wheat area of this country centers around North Dakota and neighboring states. Heisig, Ahrendes, and Merrick (2) studied wheat yields in North Dakota and attempted to evaluate the trend of yields independent of the influence of weather. Actual yields per acre for the twenty-five-year period 1919–1944, yields adjusted for major weather effects, and the trend of the adjusted yields are shown in figure 1. The increased yield is about 50 per cent for the period, which represents substantial progress. From the data available it is not possible to separate the portion of this increased yield due to varietal improvement from that due to improved cultural practices. Without question, however, varietal improvement accounts for a substantial part of the increase.

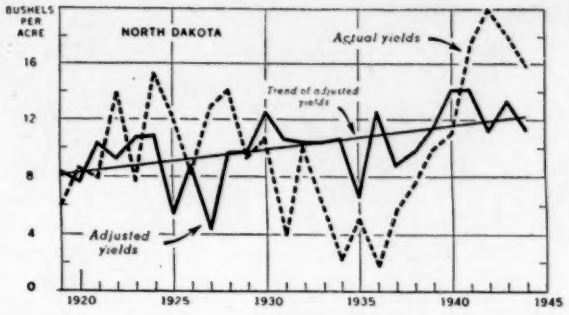

FIG. 1. Wheat yields in North Dakota showing the upward trend of yield after adjusting for the major effects of precipitation and temperature.

The history of wheat varieties in North Dakota has been reviewed by Stoa (9) and by Walster and Nystuen (11). Stoa indicates that Red Fife and selections from it were commonly grown in North Dakota until the introduction of Bluestem in the early 1890's. Durum wheat was introduced about 1900 and since 1906 has been grown on about 20 to 30 per cent of the wheat acreage of North Dakota. Mindum, a variety of amber durum released about 1917, was the most extensively grown variety for many years, but has now been partially replaced by the more stem rust resistant varieties Stewart and Carleton. Marquis wheat, developed from a cross between Hard Red Calcutta, and early ripening wheat from India, and Red Fife, was first introduced into North Dakota in 1912 and by 1919 it accounted for two-thirds of the hard red spring wheat in the state. The early maturity it obtained from Hard Red Calcutta permitted it to escape some of the damage caused by rust, drought, and heat. The Ceres variety was introduced in 1925. Ceres had some rust resistance and was an improvement over Marquis. Thatcher, released in 1934, carried improved stem rust resistance derived from durum wheat. By 1941 it accounted for 60 per cent of the hard red spring wheat of the state. The leaf rust resistance of Thatcher was

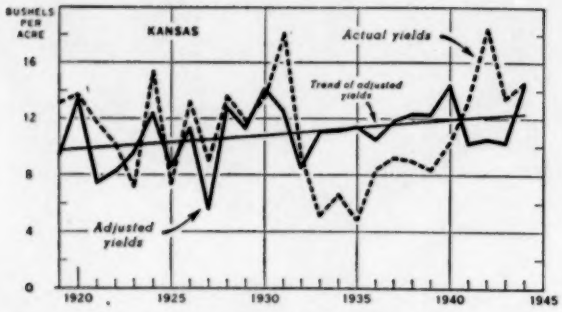

FIG. 2. Wheat yields in Kansas showing the upward trend of yield after adjusting for the major effects of precipitation and temperature.

not adequate, however, and this variety has given way to Mida, Rival, Pilot, Renown, Regent, and Cadet which carry the improved leaf rust resistance of Hope and H44. These are the first *vulgare* wheats with near immunity to most races of stem rust developed from the cross of Marquis and Yaroslav emmer.

Heisig, Ahrendes, and Merrick also studied the trend of wheat yields in Kansas, heart of the hard red winter wheat area. The results are shown in figure 2 and indicate an increase of about 20 per cent for the twenty-five-year period. Early wheat culture in Kansas centered around the Turkey variety that had been introduced from Russia about 1873. Turkey was largely replaced by Kanred, Blackhull, and Tenmarq. These have now been replaced by such varieties as Pawnee, Comanche, Wichita, Westar, and others which are earlier in maturity, more resistant to rust, smut, and in some cases to Hessian fly.

Again it is not possible to separate the contributions of varietal improvement to increased yield from those of improved cultural practices such as early plowing. It is evident, however, that winter wheat varieties for Kansas had not been improved so strikingly by 1944 as had spring wheat for North Dakota where yields had increased 50 per cent.

HYBRID CORN

One of the most spectacular increases in crop yield as a result of genetic improvement is that occasioned by the introduction of hybrid corn in the United States. It may be conservatively estimated that the use of hybrid seed corn has resulted in increased yields of at least 30 per cent on the land where it has been grown. The total annual increased production in recent years probably has amounted to about 750 million bushels. As a result of the use of hybird corn about 500 million more bushels of corn now are produced on about 15 million fewer acres than twenty years ago. Corn now has moved from third place to first place among the cereal crops of the world outside the U.S.S.R.

The use of hybrids among inbred lines for the commercial production of corn was first suggested by Shull (5, 6) in 1908 and 1909. Breeding work to develop inbred lines was initiated at several locations during the next ten years and this work was considerably expanded in the early 1920's. A few hybirds came into commercial production in the 1920's and several more entered production in the early 1930's. In 1933, twenty-five years after hybrid corn was first suggested, 143,000 acres representing 0.1 per cent of the national corn acreage were planted with hybrid seed. In 1950 hybrid corn was grown on about 65 million acres or 77 per cent of the national corn acreage. During the eighteen-year period, 1933 to 1950, inclusive, the hybrid corn acreage increased 450 fold.

The corn hybrids first developed were adapted to the Corn Belt and the use of hybrid seed corn progressed most rapidly in that region, with Iowa somewhat in the lead. The trend of corn yields in Iowa before and since the advent of hybrid corn provides an excellent indication of its influence on corn production. These yields have been charted by Sprague (7) for the eleven-year period 1933 to 1943, inclusive, in conjunction with those of tame hay and the percentages of the Iowa corn acreage planted with hybrid seed. A chart similar to that prepared by Sprague but covering the twenty-five-year period 1924–1949, inclusive, is shown in figure 3.

Prior to the advent of hybrid corn the acre

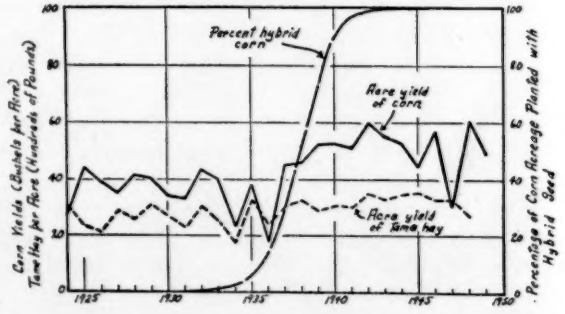

FIG. 3. Yields of corn and tame hay in Iowa showing the upward trend of corn yields associated with the use of hybrid corn.

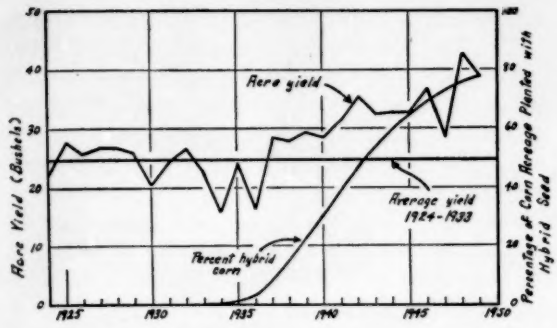

FIG. 4. Corn yields for the United States, showing the increased yields associated with the use of hybrid corn.

yields of corn and tame hay in Iowa were associated fairly closely. Since the advent of hybrid corn, however, corn yields have increased markedly, whereas those of tame hay have remained relatively constant. The average acre yield of corn in Iowa for 1924–1933, inclusive, the last ten years of favorable seasons prior to the advent of hybrid corn, was 37.8 bushels. The average acre yield for the ten years 1939 to 1949, excluding the unfavorable season of 1947, was 53.4 bushels. This is an increase of 15.6 bushels or 41.3 per cent. Most of this increased yield can be attributed to the use of hybrid seed. It is felt that such changes in cultural practices as have occurred between the two periods, could account for only a relatively small portion of the increased yield.

The national trend of average corn yields for the same twenty-five-year period is shown in figure 4. The upward trend of yields since 1938 is very evident. On a national basis, however, it is difficult to estimate the amount of increased yield resulting directly from the use of hybrid seed corn. In the Southeastern States for example, much of the increase in yield has been obtained as a result of larger fertilizer applications and improved production methods directly associated with the use of hybrid seed. Hybrids have demonstrated an ability to make efficient use of larger amounts of plant food elements and hence larger fertilizer applications are recommended for them than were used on the open-pollinated varieties formerly grown.

RICE IMPROVEMENT

As an example of accomplishments in rice improvement I have chosen those that have occurred in Japan. The improvement in rice production in Japan has recently been summarized by Salmon (4) for the sixty-five-year period from 1878 to 1942. Rice is the most important single crop and the basic food crop of Japan. Rice improvement, therefore, has received considerable attention. The average acreage, production, and acre yield of rice in Japan by five-year periods as reported by Salmon are shown in figure 5. These records indicate that, the acreage has increased about 25 per cent,

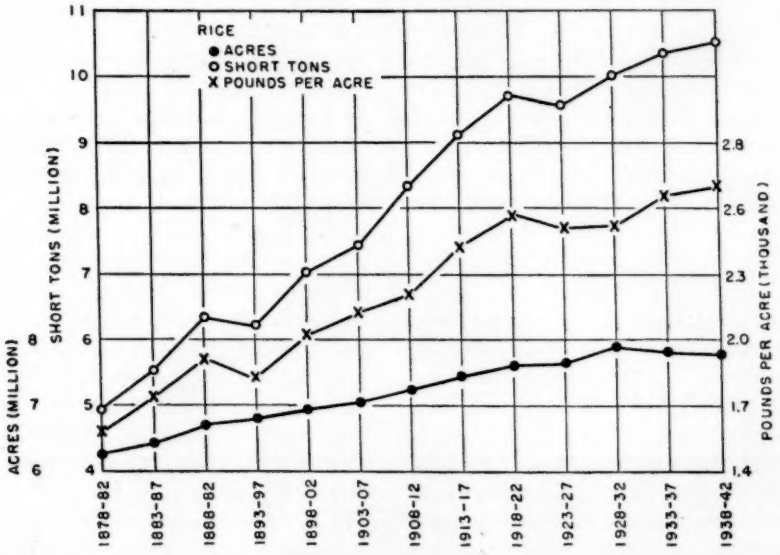

FIG. 5. Average acreage, production, and yield per acre of brown rice (hulls removed) in Japan by five-year periods, 1878–1942.

yield per acre 70 per cent, and total production 113 per cent during the sixty-five-year period.

Salmon indicates that the two factors that appear primarily responsible for the increased production are the use of commercial fertilizers and better varieties. He also indicates that Japanese investigators believe they cannot be separated since each is dependent on the other. He states that "it seems to be the general belief that the better varieties produced in recent years are better only when heavily fertilized and also that the better varieties must be grown if the full benefit of fertilizers are to be expected."

New rice varieties produced by the agricultural experiment stations now are widely grown, one estimate indicating that they constituted no less than 69 per cent of the total rice acreage of Japan in 1945. Of these new varieties an extimated 46 per cent were produced by hybridization and 23 per cent by selection from old varieties. Improvement by hybridization is of relatively recent origin, having been employed to an important degree only since 1920, although it had been used to some extent since 1903.

Important features of rice improvement in Japan have been the development of varieties resistant to blast, and hardy varieties that that tolerate low summer temperatures. Blast, *Piricularia oryzae*, is the most important rice disease in Japan. Resistance to blast was discovered in certain varieties from India and these were hybridized with Japanese varieties. Rikuu-132, the first resistant variety developed, was distributed in 1925. The hardy varieties are needed in northern Japan to tolerate low temperatures during the early growing season and and also at heading time and later. Early maturing hardy varieties also have been developed which has permitted the extension of rice culture in Hokkaido to the northern parts of the island.

POTATO IMPROVEMENT

The potato follows cereals in importance as a world food crop. Like corn, it is a native of the Western Hemisphere. Unlike corn, however, the intensified region of potato culture has moved from the Americas to Europe since it was first introduced there a little less than four hundred years ago. According to Stevenson (8) the average world production for the prewar period of 1935–1939 was a little less than 8.5 billion bushels. About 90 per cent of this was produced in Europe, including the U.S.S.R.; 5 per cent was produced in North America; nearly 3 per cent in Asia, excluding the U.S.S.R.; 1 per cent in South America; and less than 1 per cent in Africa and Oceania.

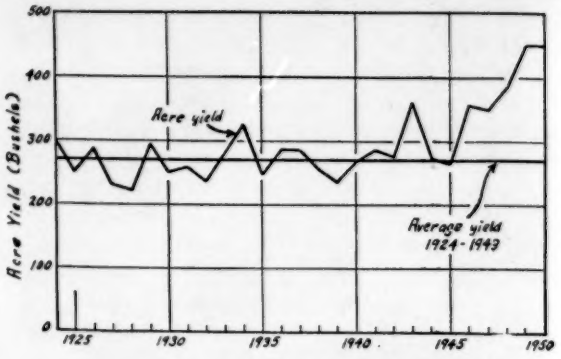

FIG. 6. Potato yields in Maine.

Potato improvement in Maine, by far our largest potato-producing State, has been chosen as an example of the genetic improvement of this important crop. Twenty-five years ago the principal potato varieties grown in Maine were Green Mountain, Irish Cobbler, Triumph, and Spalding Rose. Although these varieties are high yielding and have good cooking quality they are very susceptible to diseases and insects. Potato improvement, therefore, has been centered on the development of disease-resistant and insect-resistant varieties that were productive and had good market quality.

Data on the acre yields of potatoes in Maine for the twenty-five-year period from 1924 to 1949, inclusive, and the average yield for the twenty-year period 1924 to 1943, inclusive, are shown graphically in figure 6. During the first nineteen years acre yields were rather stable. The large yield obtained in 1943 is attributed mainly to an exceptionally favorable season. This stability in itself, however, was greatly influenced by by the varietal improvement resulting from breeding work started in 1910 and greatly expanded in 1929. According to Stevenson (8) the upward trend of acre yields in recent years is due to the development of high-yielding, disease-resistant varieties, improved fertilizer practices, improved fungicides, improved spraying and dusting equipment, and the increased use of certified seed.

The overall contributions of the improved varieties to increased production have been very large but are difficult to estimate accurately. The first of the disease-resistant varieties devel-

oped was Katahdin which was bred for resistance to mild mosaic and was distributed in 1932. It has since been shown to have some resistance to leafroll and is immune to net necrosis. In addition it is widely adapted and has excellent market quality. The Chippewa variety was released in 1933. It is immune to mild mosaic and does not contract net necrosis but is very susceptible to leafroll. It is a more consistant yielder than Green Mountain and matures ten days to two weeks earlier. Sebago is more resistant to late blight than any of the old commercial varieties. It was released in 1938 and is immune from mild mosaic in the field, has not developed net necrosis, and is more resistant to scab than Irish Cobbler or Green Mountain. Its tubers also are resistant to the rots caused by the late blight fungus (*Phytophthora infestans*). It is estimated that about 90 per cent of the varieties now grown in Maine are new varieties bred for disease resistance.

The most destructive potato disease has been late blight. Immunity from blight was discovered in a wild species of potato from Mexico (*Solanum demissum*) during the first decade of this century. Crosses between this species and cultivated varieties of *S. tuberosum* have yielded some very promising new varieties. Kennebec, a variety recently released, is immune from the common forms of leaf blight in Maine and is highly resistant to many other forms occurring throughout the United States. It is somewhat resistant to scab and has never contracted mild mosaic or net necrosis, but is susceptible to leafroll and spindle tuber. Kennebec and other newly released varieties as yet have had no influence on the recent upward trend of potato yields in Maine. These varieties, however,

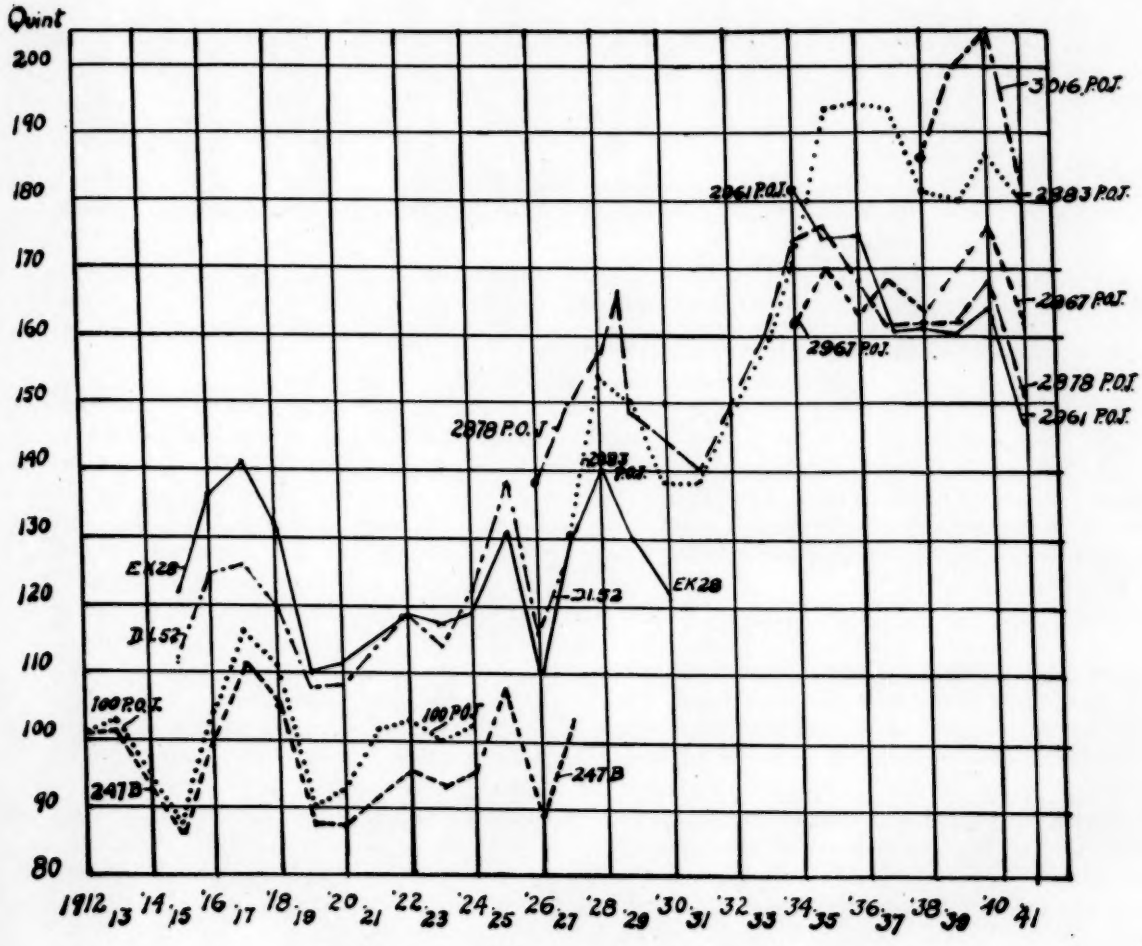

FIG. 7. Sugar yields in Java in quintals per hectare.

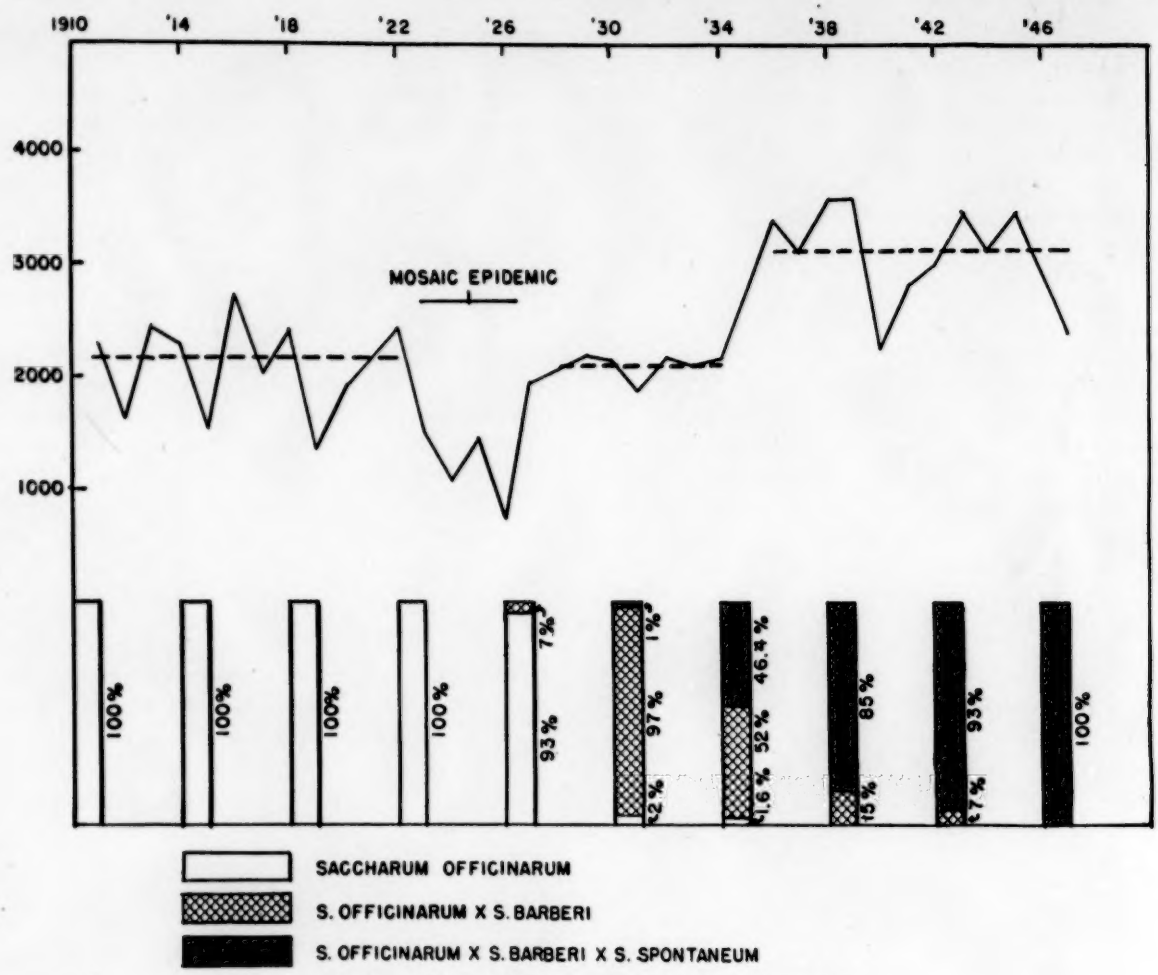

FIG. 8. Sugar yields in Louisiana in pounds per acre.

indicate the possibilities of a continued upward trend of yields in future years. No variety yet released has been immune from all of the important potato diesases. The examples cited, however, indicate that rapid progress is being made in this direction.

SUGARCANE IMPROVEMENT

The improvement of sugarcane by breeding has presented a number of special problems. Commercial sugarcane is propagated vegetatively by the use of stem cuttings, or seed cane, rather than by seed. Vegetative propagation preserves the purity and characteristics of each variety. The flowers of most of the cultivated varieties are male sterile, that is they produce no viable pollen and must be cross pollinated in order to set seed. Many of the cultivated varieties produce seed only sparingly or not at all.

There are three cultivated species of sugarcane and two principal wild species, each containing numerous varieties. The five species differ in chromosome number but it has been possible to cross particular varieties in the different species. Hybridization has been extensively used to introduce disease resistance, to obtain better local adaptation, and to obtain hybrid vigor. The technic of utilizing hybrid vigor in sugarcane is quite different from that in corn. It is not feasible and not necessary to develop inbred lines in sugarcane. Crosses are made directly between varieties. Since the varieties are extremely heterozygous the progeny from such crosses yield a wide range of types. The plants obtained must be studied and evaluated individually. Outstanding individuals are propagated vegetatively as a clone.

The contributions of hybrid vigor to increased

yields of sugar in Java and Louisiana have been summarized recently by Brandes (1). The genetic constitution of cane varieties in Java and their yields of sugar in quintals per hectare, from 1912 to 1941 are shown in figure 7. The varieties on the left are *Saccharum officinarum* intra-specific hybrids which, according to Brandes, already had attained a production level above that of the original varieties of *S. officinarum* previously grown. The varieties at the right are *S. officinarum* × *S. spontaneum* inter-specific hybrids. These have proved much more productive than the older varieties. Brandes indicates that the increased yields obtained can be attributed to varietal improvement as "there were no other obvious factors such as epidemics of disease or drastic changes in field practices to account for the different levels."

The genetic constitution of the sugarcane varieties grown in Louisiana from 1910 to 1946, and sugar yields for the same period, are shown in figure 8. Varieties of *S. officinarum* were grown prior to 1927. These were susceptible to disease, however, and the industry was almost destroyed by mosaic and red rot in the middle 1920's. Resistance to mosaic was introduced from *S. barberi* and yields were restored from 1928–1934 when bi-species hybrids were adopted. The yield record of tri-species hybrids representing extractions of *S. officinarum*, *S. barberi* and *S. spontaneum* in different combinations is shown at the right for 1936 to 1947. This mean level of yield is about 25 per cent higher than that of the original *S. officinarum* varieties shown on the left.

DISCUSSION

The examples presented above indicate that the genetic improvement of food plants has materially increased the yield obtained from them. The specific amount of the increased yield that can be attributed to genetic improvement, however, cannot always be ascertained with accuracy. The examples also indicate that different kinds of genetic improvement have operated in the different crop plants. The development of disease resistant varieties has been of special importance in the case of wheat, potatoes, and sugarcane. Hybrid vigor has been successfully used in corn and sugarcane. Breeding for adaptation to local environments has been of importance in all crops.

In view of the accomplishments now made it may well be asked as to what are the possibilities for the future genetic improvement of these crops. In the case of hybrid corn, my own specialty, I am certain there are excellent possibilities for much further genetic improvement for increased yielding ability. Breeding technics have been improved and we now have more efficient methods of determining the yielding potential of parent lines than were available in the past. This should permit the development of hybrids with still greater plant vigor. Corn diseases and corn insect pests take a large toll of our production each year. Resistance to many of these diseases and insect pests already has been identified but the task yet remains to combine the various resistances and to incorporate them into the hybrids that make up the commercial corn crop.

Possibilities for future improvement of other food plants seem fully as great as those in corn. Plant breeding is a slow and painstaking process. With most food plants it is possible to grow only one or possibly two generations a year and large numbers of plants are needed to obtain the desired kinds of individuals. We can be quite assured, however, that progress will be certain and that the rate of progress will be roughly proportional to the effort expended.

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RANDOM ELEMENTS IN THE FORMULATION AND EXECUTION OF FOREIGN POLICY

PHILIP C. JESSUP

United States Ambassador at Large

(*Read October 26, 1950*)

IT IS probably an undesirable practice to have titles for lectures such as this. The title rarely helps the listener to understand what the speaker wishes to say. Certainly, the title should not be written until after the speech is completed but in this case the exigencies of programming and other obligations necessitated selecting a title first. As you will readily detect, this title was selected with a view to allowing considerable latitude in the content of the remarks which would be made under it. I shall be very frank in exercising such latitude and will not aspire to Humpty Dumpty's dictatorial mastery over words to make the title and the body of the address conform. It may very well be that you will conclude that it is the thoughts and not the elements which are random.

I do want to emphasize that I am not proposing to argue which elements in the formulation and execution of foreign policy are random or capricious and which are fundamental or constant. In effect, I propose to suggest for your consideration some of the elements which actually enter into the situation and to which perhaps at times insufficient attention is directed. If apology be due for this somewhat disorganized approach to the subject matter, I beg to submit my apology herewith and to proceed untrammeled by any semantic servitude. Nonetheless I shall return later to the power of words as one of the random elements.

It might be convenient to begin with the definition of foreign policy but definitions can be as misleading as titles. I have never been able to bring myself to consider a definition sacred even though it is printed in a book as big as a dictionary. As Judge Cardoza said of definitions of law, if the result of a definition is to make facts seem to be illusions, "so much the worse for the definition; we must enlarge it till it is broad enough to answer realities."

I have, however, recently seen this definition of foreign policy: "Our foreign policy is the sum total of the aspirations and reactions of the American people, as channeled up through the executive branch of the Government and through Congress." The same statement wisely went on to say that foreign policy is necessarily fluid. "By its essential quality it is neither static nor the conscious decision of one man or one group of men. . . . Some problems cannot ever be permanently 'solved.'"

The very adjective "foreign" has been sufficient in periods of our history to damn the noun to which it was attached. The only exceptions have been the committees of the Senate and House which deal with "Foreign Relations" and "Foreign Affairs." Dr. Nicholas Murray Butler used to argue vehemently that these titles should be changed to "International Relations" and "International Affairs" in order to cut the psychic fringe from the word "foreign" in the American mind.

In any case, foreign policy used to be considered a mysterious and esoteric thing. Nowadays everybody is an expert on it. This in itself is excellent. Many of the "experts" misunderstand and misrepresent but they are interested and sometimes interesting. The real danger comes from popular indifference. That indifference has largely been swept away by the realization that foreign policy has to do very intimately with a vast number of questions which closely touch the lives of people in this country as in all other countries.

It is neither easier nor more difficult to explain what foreign policy is than to explain what domestic policy is. Our domestic policy in any period includes an enormous range of subject matter, from taxes, social welfare, labor, to conservation, crime, commerce, and agriculture. Foreign policy takes into account all these and many other problems. As Mr. Acheson recently stressed it "is not a disembodied thing."

It is helpful to bear in mind the difference between general and particular policies. As Mr. Justice Holmes used to say, "General principles

do not decide concrete cases." It is a general foreign policy of the United States, for example, to support the United Nations. This general policy alone does not provide automatic answers although it is a helpful guide. It was certainly a guide to the decisions made on June 25 regarding Korea. But since the scope of activities of the United Nations also covers practically every human endeavor, particular policies must be formulated and carried out in regard to special propositions.

In a preliminary way I should like to point to certain elements in the formulation of foreign policy which are perhaps quite obvious but which should not for that reason be ignored.

In the formulation of foreign policy one must start with a body of information or knowledge. The breadth and scope of this necessary body of knowledge is really staggering. It covers practically the whole range of subjects included in the Social Sciences. It must comprise a blending of historical, political, economic, sociological, psychological, and other factors. In many instances military elements may be of the highest importance. It must have its roots in history, be economically sound and politically feasible. Some one has said that "Politics has been described as the art of the possible. To broaden the area of the possible is the art of statesmanship." Political feasibility involves not only the international scene but an appreciation of domestic factors such as Congressional attitudes which in turn may reflect trends in American public opinion. In appraising the attitudes of foreign governments, public opinion trends in those countries must also be taken into account. If statesmanship is to broaden the area of the possible, it may need to influence public opinion. The execution of the foreign policy of any government includes this task.

The geographical range of the body of knowledge in question must also be practically global. Even if the policy to be formulated is primarily bilateral in character its effect may be felt in many other quarters. These considerations must be weighed.

The body of knowledge may be utilized either as bricks from which a structure is gradually built or as laboratory apparatus in which an idea is tested.

Since omniscience is not a quality vouchsafed to man, it is not a human possibility to cover every situation in advance by a neat specification of action to be taken in every contingency which may subsequently materialize.

What one can say is that general long-range policy must come first and particular policy must be consistent with it. The special train must run on the same tracks which carry the regularly scheduled traffic.

Similarly, in coming to the question of the execution of foreign policy there is no such thing as omnipotence. We do not even aspire to a position in which we ourselves could make the foreign policies of all other friendly governments. It is fortunate that this is so. History is replete with the tragedies caused by those who have sought for omnipotence in making their will or policy prevail throughout the world. While the limits on the power to execute policy should be obvious, they are often overlooked with the consequence that impossibility is sometimes confused with incompetence or indecision. These unhappy elements may undoubtedly appear in any human operation but they cannot be assumed, much less proved, by the fact that something is not done at a particular time in a particular way.

One of the occupational hazards of diplomacy is that details of negotiations cannot be published from day to day. One of our ablest contemporary journalists has said that there is an "area of secret information where the reporter's job is to disclose and the responsible official's job is to conceal." I would not dare to speak on the responsibility of journalists, but it is true that those officials having to do with the formulation and execution of foreign policy have a responsibility for keeping secrets. Indeed, our statutory law makes it a criminal offense for them to disclose certain information.

The problem is to reconcile this responsibility with the companion duty which rests on government to keep the people informed. Secretary of State Acheson has well said that "The inherent strength of our system is the responsiveness of the Government to an informed and critical public opinion. It is precisely this informed and critical public opinion which totalitarian governments, whether Rightist or Communist, cannot endure and do not tolerate."

The reasons why it is important not to disclose all details of information affecting foreign policy are easily understood. A large part of the execution of foreign policy involves a process of negotiation. Negotiation is in turn a process of adjustment. If one begins a negotiation by publish-

ing in the press all of the details of one's positions and the reasons for those positions one obviously loses advantage. This is common to all types of negotiation whether in business or in any other field. There is an added element in a diplomatic negotiation that if one begins by announcing all desirable conditions and then in the course of negotiation finds it necessary to yield on certain points in order to get agreement on the main principles, one is likely to arouse a popular feeling that there has been a surrender.

I would not like to leave the impression that diplomatic negotiation is merely a process of bargaining as if one were engaged in horse trading. I would re-emphasize the point that it is the problem of adjustment and reconciliation of sometimes conflicting interests which is involved. The need for such adjustment is one of the factors which could be eliminated only by the omnipotence which does not exist. It is also frequently true that a government with whose representatives negotiations may be carried on, finds it necessary to consult its parliamentary leaders before making an agreement firm. They must be allowed to disclose, explain, and persuade as they think best. Premature disclosure by the other party to the negotiation may well prejudice making those domestic adjustments which are frequently as important as the international adjustments.

There is another important aspect to this problem. Much of the international negotiation which takes place today is carried on multilaterally. This process is particularly essential in the operations of the United Nations. There one is involved in a broad consultative process. Most of the important resolutions which are passed by the General Assembly of the United Nations, for example, are the result of joint drafting or else reflect numerous suggestions incorporated after ascertaining the views of many delegations. It is physically impossible to consult everyone at the same moment. The only way in which a kind of simultaneous consultation could be achieved would be through the submission of a text to the Assembly or one of its committees without prior discussion. This in effect would be the negation of the consultative process. It is frequently necessary to consult on the representative principle in the sense that discussions with one or more delegations may elicit the views of a group of delegations which work closely together. This consultative process is inevitably hampered and may be totally frustrated by premature disclosure which antedates consultations which are about to take place.

The first of Wilson's Fourteen Points reads as follows:

> 1. Open covenants of peace, openly arrived at, after which there shall be no private international understandings of any kind but diplomacy shall proceed always frankly and in the public view.

Wilson himself did not follow this precept literally at Paris. The complaints about the secrecy of the meetings of the Big Four were of the usual intensity. The Fourteen Points were stated in President Wilson's speech to the Senate on January 8, 1918. By September 27 of that year, Point One had been reduced to its essentials in an address opening the Fourth Liberty Loan Campaign, ". . . all international agreements and treaties of every kind," President Wilson said, "must be made known in their entirety to the rest of the world." He was striking at the historical evil of secret treaties of alliance. It was only this residue that was incorporated in Article 18 of the Covenant of the League of Nations and remains in Article 102 of the Charter of the United Nations. Article 18 of the Covenant declared that no treaty was binding until registered with the League. An abundant and learned literature of legal comment upon this article attested more to the novelty of the provision than to its lack of clarity. The Charter provision ingeniously takes care of the technical problems raised by the Covenant but scrapes even more paint from the picture Wilson first painted in such broad strokes. Article 102 of the Charter requires registration of treaties and agreements, but as a sanction for non-compliance prevents a party to an unregistered treaty from invoking it before any organ of the United Nations. This is sensible and practical but it is not at all the same principle of international ethics to which Wilson first aspired.

I doubt the validity of his original principle. Secret negotiations are not in themselves noxious. The parental conspiracies at Christmas time make the practice familiar to us in our childhood. Secret societies are inevitable and perhaps take firm hold on the youthful imagination almost as soon as the Santa Claus myth has been discarded. An engagement to marry is usually in modern days the result of a secret negotiation ending in an agreement which for a time at least is often secret. Similar lack of publicity characterizes business negotiations. The deliberations of a jury